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Boll Weevil and Cotton Aphid Control by the Use of Derris in Combination with Calcium Arsenate

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In preliminary tests at Florence, South Carolina, in 1939 derris in combination with equal parts of calcium arsenate and either sulfur or diatomaceous earth gave outstanding results in preventing the increase of cotton aphids; *Aphis gossypii* Glov. (Bondy & Rainwater 1939). To determine more definitely the efficacy of such a combination in the control of the boll weevil, *Anthonomus grandis* Boh., and the cotton aphid, experiments were conducted in 1940 at several locations, namely, State College, Mississippi, Tallulah, Louisiana, and Waco, Texas, as well as Florence.[1]

Materials and Methods.—The insecticides tested are listed in table 1. The mixtures containing derris were prepared at the Tallulah laboratory just before dusting began and were identical in all experiments. The derris powder was analyzed by the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine and enough ground root added to contain 0.5 per cent of rotenone in the final mixtures. The calcium arsenate contained from 7 to 8.6 per cent of water-soluble arsenic pentoxide by the New York method and approximately 42 per cent of total arsenic pentoxide. Since the principal objective was to determine whether the addition of derris to the calcium arsenate used in a heavy dusting schedule would prevent the usual build-up of aphids, eight effective applications were made at 5-day intervals commencing when the first blooms appeared on the cotton, irrespective of the boll weevil infestation. The treatments were made with single-nozzle rotary hand dusters in the early morning when the plants were moist with dew. Calcium arsenate with and without derris was applied at the rate of about 6 pounds per acre per application and the calcium arsenate-sulfur mixtures at about 12 pounds per acre. Since one of the derris mixtures was applied at twice the rate of the other, it may be seen that one set of plots received twice as much rotenone as the other.

At each location each treatment was replicated four times in a randomized block of 20 plots. The plots were 10 rows wide and of sufficient length to constitute an area of one-eighteenth acre. The entire plots were dusted, but records were taken from a sample area of one-fiftieth acre in the middle of the four center rows in each plot.

The manner in which the data were obtained was similar at each location. Boll weevil infestation records were made by examining 100 squares near each end of the sample area of each plot at weekly intervals and recording the number of punctured squares. Records on aphid populations were made by making weekly counts of the aphids on 1 square inch of leaf area from each of 50 leaves located near each end of the sample area of each plot. The fourth leaf from the top of the plant was selected as the sample leaf at each examination. The infestation records of boll weevils and aphids were begun immediately after the first poison application and were continued until the cotton was mature. Yield records were made by picking all the cotton produced on the sample area and recording this as pounds of seed cotton per plot. Owing to a combination of circumstances, yield records were not obtained from the State College experiment.

Results.—Data on boll weevil and cotton aphid infestations, as well as cotton

[1] The data from State College, Tallulah, and Waco were obtained under the supervision of R. L. McGarr, R. C. Gaines, and K. P. Ewing, respectively.

yields, at the different locations following the various treatments are shown in table 1. By the method of analysis of variance the minimum significant differences at the 5- and 1-per cent levels were determined for the three sets of records at each locality. Because the boll weevil infestation at Florence and the aphid infestation at Waco were extremely light, no attempt was made to subject these data to statistical analyses.

DISCUSSION.—The data presented in table 1 show that at each location except Florence there was a highly significant difference in boll weevil infestation between each of the treatments and the checks, with no significant difference between any two treatments.

In number of aphids per square inch of leaf area highly significant differences favoring the treatments which contained derris over those which did not are shown at all locations where heavy infestations occurred. At State College and Tallulah, but not at Florence, there were highly significant differences favoring the calcium arsenate-sulfur-derris treatment over the calcium arsenate-derris treatment. At State College there was a highly significant difference favoring the calcium arsenate-sulfur treatment over calcium arsenate alone, but at Tallulah and Florence no significant difference occurred. At State College and Tallulah the plots treated with calcium arsenate-derris mixture showed significantly more aphids than the check plots, but those treated with calcium arsenate-sulfur-derris mixture did not. At Florence, however, there were significantly more aphids on the check plots than on plots receiving the calcium arsenate-sulfur-derris treatment, but not on the check plots as compared with those receiving the calcium arsenate-derris treatment.

At Florence and Tallulah the addition of derris to the calcium arsenate significantly increased the yields over calcium arsenate alone, and at Tallulah the addition of derris to the calcium arsenate caused a significant increase in yield over the check plots. No other significant differences in yield occurred. At Waco, although there were significant increases in yield favoring all treatments over the check, there were no significant differences between treatments.

It will be seen that, on the whole, yield data do not support the boll weevil infestation data in determining the effect of the insecticide on the weevil. This fact has been brought out in previous publications (Rainwater 1938, 1939; Bondy 1939; Gaines *et al.* 1940; Rainwater & Bondy 1941). It often happens that yields are less on plots treated with calcium arsenate than on comparable untreated plots. This discrepancy has been correctly attributed to injury caused by cotton aphids, which often more than offset the gains that might result from the control of light weevil infestations. The yield data in comparison with the aphid population in table 1 bear out these facts. The insecticides which did not contain derris gave highly significant boll weevil control over the checks, permitted highly significant infestations of aphids to develop over checks, and produced no significant increases in yields over the checks. But when the aphids were

Table 1.—Results of tests with calcium arsenate and calcium arsenate-derris mixtures for the control of the boll weevil and the cotton aphid, 1940.

Treatment	Average Seasonal Boll Weevil Infestation, Per Cent				Average Number of Aphids per Square Inch of Leaf Area				Average Yield of Seed Cotton per Plot, Pounds[1]		
	Florence (4 counts)	State College (6 counts)	Tallulah (5 counts)	Waco (5 counts)	Florence (5 counts)	State College (7 counts)	Tallulah (7 counts)	Waco (6 counts)	Florence	Tallulah	Waco
Calcium arsenate	0.19	2.18	8.45	12.53	6.00	11.40	7.28	1.10	22.45	19.91	29.74
Calcium arsenate plus:											
Derris 92–8 (0.5% rotenone)	.44	4.58	11.03	15.90	2.10	3.65	3.98	.33	25.08	22.36	28.28
Sulfur 50–50	.25	3.00	9.75	13.93	7.90	8.70	6.03	.48	22.88	20.39	29.76
Sulfur and derris 46–46–8 (0.5% rotenone)	.13	4.10	9.38	13.73	1.10	1.05	1.85	.10	23.58	20.95	29.28
Check	.57	9.00	14.68	29.88	4.03	1.88	2.40	.10	23.25	20.25	26.61
Minimum significant difference:											
5% level		2.47	4.32	8.61	2.56	1.83	1.34		2.27	1.89	1.65
1% level		3.46	6.06	12.08	3.59	2.57	1.87		3.18	2.65	2.31

[1] No records taken at State College.

controlled by the addition of derris to the calcium arsenate, there were significant increases in yields over plots treated with calcium arsenate alone at both Tallulah and Florence.

Additional experiments conducted at Florence and State College support the results that the cotton aphid can be successfully controlled by the addition of derris to calcium arsenate or to mixtures of equal parts of calcium arsenate and sulfur or diatomaceous earth. Additional observations supporting these results were also made in Pamlico County in North Carolina, where a group of interested farmers used a commercially prepared mixture consisting of equal parts of calcium arsenate and sulfur containing enough ground cube root to make the final mixture contain 0.5 per cent of rotenone. As many as 10 applications of this mixture were applied to cotton on several farms without any apparent increase in aphids.

It should be stressed in this connection that the aphid control obtained from the addition of derris to the materials referred to above is indirect; that is, the aphids are controlled by keeping injurious numbers from developing rather than by controlling injurious numbers after they have been allowed to develop. Unpublished results and observations indicate that heavy infestations of the cotton aphid cannot be successfully controlled by the use of derris at the concentrations ordinarily used in dusts or sprays. The experiments do show, however, that injurious numbers of cotton aphids will not occur as a result of dusting cotton with calcium arsenate for boll weevil control if each application of the calcium arsenate used contains as much as 0.5 per cent of rotenone. Likewise, no claim is made that the mixtures discussed will remain effective after a prolonged period of storage. It is not known how long a mixture of derris and calcium arsenate will remain effective, and for the present only freshly prepared mixtures are recommended.

Whereas 0.5 per cent of rotenone added to calcium arsenate or to mixtures of calcium arsenate and sulfur will control the cotton aphid, it is not known whether a smaller percentage will give adequate control. Also, the question of the best diluent, or whether to use a diluent at all with the calcium arsenate, is not satisfactorily answered. These and other problems that will doubtless arise can only be answered by future experiments.

SUMMARY AND CONCLUSIONS.—In identical experiments conducted at Florence, S. C., State College, Miss., Tallulah, La., and Waco, Tex., in 1940, four insecticides or combinations of insecticides were tested against the boll weevil *Anthonomus grandis* Boh., and the cotton aphid, *Aphis gossypii* Glov. The materials tested were calcium arsenate with and without derris at the rate of 6 pounds per acre per application and equal parts of calcium arsenate and sulfur with and without derris at the rate of 12 pounds per acre per application. Eight effective applications were made at each location. Analysis of the data showed that there was no significant difference in the degree of boll weevil control between any two insecticides and that each insecticide was significantly better than the check. Aphid population counts showed highly significant differences favoring the insecticides which contained derris over those which did not. Yield records showed that calcium arsenate plus derris was significantly better than calcium arsenate alone.—3-8-41.

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Secondary Hosts of the Pink Bollworm in the Lower Rio Grande Valley of Texas and Mexico

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Investigation of secondary hosts of the pink bollworm, *Pectinophora gossypiella* (Saund.), as a phase of the research program in the Lower Rio Grande Valley of Texas and Mexico has been in progress since the laboratory of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, was established at Brownsville, Texas, in June 1939. Cotton, the preferred host plant, and all the known secondary hosts of the pink bollworm belong to the order Malvales. The flora of the Lower Rio Grande Valley is rich in malvaceous plants, and some 50 species are known from this section. Some species occur in great abundance along canal banks and roadsides and in waste places. Since all the Malvaceae with seed pods sufficiently large to support larvae may be considered as potential hosts, information on their importance in maintaining the pink bollworm is needed.

Okra, *Hibiscus esculentus* L., is a well-known secondary host of the pink bollworm and ranks next to cotton in importance. About two thousand acres are grown commercially in the Lower Valley for table use and for the production of seed, most of which is shipped to other areas. In the Lower Valley the first infested okra pods were found on August 15, 1939, when two pink bollworm larvae were taken from green pods collected in the southern part of Cameron County, Tex. Since then many infestations have been found in okra on both sides of the Rio Grande during the period August to December. Dry pods with hibernating larvae have been found in December, an indication that okra might serve as an overwintering host. The highest infestation found in okra was 8 per cent in a very limited number of pods. Regulations have been promulgated to safeguard the movement of green okra or okra seed to uninfested areas and to limit the period when okra is allowed to fruit in the Lower Valley.

[1] All members of the Brownsville, Tex., laboratory assisted in the investigations reported in this paper.

[2] In cooperation with the Delegacion de Defensa Agricola of Mexico and the Texas Agricultural Experiment Station.

The next secondary host found was wild turk's cap, Texas mallow, or manzanita, *Malvaviscus drummondii* Torr. & Gray, when one larva was taken from a scarcely mature fruit near Brownsville on September 15, 1939. Repeated examinations of blooms and fruit of this species for pink bollworms were made during the fall and winter of 1939–40, but none were found. During the fall of 1940, however, seven larvae were found on examination of 5,000 fresh blooms of *M. drummondii* collected near Matamoros, Tamaulipas, Mexico, on October 4, and 48 moths emerged in a cage containing approximately 15,000 blooms and fruit collected near infested cotton fields 1 and 7 miles northwest of Matamoros from October 3 to 31. The moths emerged between October 22 and December 5 from both blooms and fruit, an indication that either furnished sufficient nourishment for development. No pink bollworm moths have emerged since December 5. During the fall of 1940 blooms and seed capsules of *M. drummondii* were collected from many localities on both sides of the Rio Grande in the Lower Valley, but at only two points were the plants found to be infested, and these plants were adjacent to infested cotton fields.

Malvaviscus drummondii has been found in many places in the lower Rio Grande Valley on both sides of the river and has been recorded by Cory & Parks (1937) in other sections of Texas. In addition to Texas, it has been recorded by Van Dersal (1938) in a portion of Florida, along the entire Gulf Coast between Florida and Texas, and along the Atlantic Coast between Florida and Pamlico Sound, N. C.

Observations indicate that *Malvaviscus drummondii* prefers a well-drained soil, rich in humus. It has been found in jungle-like woods, along canal banks and fence rows, on river and irrigation levees, and on other waste land. It has occasionally been seen as a cultivated ornamental at Brownsville and as plantings for roadside beautification along the Brownsville-San Benito highway. *M. drummondii* is a prolific

bearer in this area during almost the entire year except when affected by subnormal temperature or rainfall.

The third secondary host found in the Lower Rio Grande Valley was *Pseudabutilon lozani* (Rose) R. E. Fries, a mallow from which two pink bollworm moths emerged. The first moth emerged November 19, 1940, from a mixture of 125 flower buds and seed pods collected at Rangerville, Cameron County, Texas, November 1. The second moth emerged December 18 from a lot of 1,500 flower buds and seed pods collected between November 1 and 6 at Monte Cristo, Hidalgo County, Texas, and Rangerville and La Paloma, Cameron County.

Pseudabutilon lozani is a perennial which has been found in Cameron, Willacy, Kenedy, Hidalgo, Starr, Zapata, Duval, Webb, and Maverick Counties in Texas, as well as in the state of Tamaulipas, Mexico, from near the mouth of the Rio Grande to a distance of 125 miles west. Although this species is present at locations where the topography is slightly rolling and the soil fertile, it apparently prefers a well-drained soil and is often found on hilltops where soil is scarce. *P. lozani* under favorable conditions fruits throughout the year but more abundantly in the spring and fall.

Many other wild and cultivated mallows, some known in other parts of the world as hosts of the pink bollworm, were examined for the insect with negative results. Not enough information has been obtained regarding *Malvaviscus drummondii* and *Pseudabutalon lozani* as host plants of the pink bollworm to determine their importance in connection with the pink bollworm problem.—3-12-41.

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Studies of Insect Damage to Cotton with Reference to Soil-Conservation Practices

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In recent years much attention has been directed to conservation. The word "conservation" is now heard in connection with almost every phase of scientific research, and the term in its broadest sense is being used now as never before in nearly every important nation of the world.

F. C. Bishopp (1938), in his presidential address on "Entomology in Relation to Conservation," before the American Association of Economic Entomologists at Indianapolis, Ind., in December 1937, made the following statements: "Insects have demonstrated repeatedly that they must be reckoned with in almost every field of human activity. Any large-scale changes in land use are certain to affect insect populations and insect depredations. There is abundant evidence that the rapid clearing of forests and breaking of prairies for agricultural purposes following the pioneering period in this country led to increased destruction of the cultivated crops by insects. It is difficult to predict with accuracy what may be the effects of the reverse process on insect problems. . . . "

Perhaps the most important studies and practices pertaining to conservation are those regarding the soil. It is well known how the program of the Agricultural Adjustment Administration reaches, in one way or another, nearly every farmer in the United States. The fundamental principles of this program are based upon the conservation of the soil.

Proper soil-conservation practices usually involve changes in land use and types of crops. Such changes often result in increased entomological problems. Instances of increased abundance of the grasshoppers, the chinch bug, several species of

cutworms, the hessian fly and certain species of wireworms, following adoption of soil-conservation practices, were cited by P. N. Annand (1940) in an address before the American Association of Economic Entomologists at Columbus, Ohio, in December 1939. In connection with the studies to be described in this paper, it is desired to call attention to the following statement in Dr. Annand's address: "It does not follow, however, that such practices as do increase insect abundance are in themselves bad. Not infrequently slight modifications may be made which will eliminate the undesirable entomological effects and still achieve the desired result."

THE PROBLEM.—The studies herein described are being undertaken to help answer questions that have arisen as to the effect of the latest farming and conservation practices in the Blacklands of Texas on injurious cotton insect populations and damage or benefits that may result. We should determine whether under improved farming practices the increased acreages of corn, grains, legumes, and other soil-building or erosion-control crops increase the available food supply for thrips, cutworms, army-worms, aphids, stink bugs, and bollworms, and thereby result in additional damage to the reduced acreage of cotton. Furthermore, will the more succulent growth of cotton due to improved practices provide a more attractive plant for the cotton flea hopper, bollworm, boll weevil, and other insects, and result in greater damage to the cotton? Preliminary investigations in other areas have indicated that strip cropping gives a certain amount of protection to cotton from cotton flea hopper invasion and damage. If this soil-conservation practice proves to be beneficial in lending protection against cotton-insect injury, then there will be an additional incentive for cotton farmers to adopt it in their land-use program.

COOPERATION AND LOCATION OF STUDIES.—The studies are being conducted through the cooperation of the Bureau of Entomology and Plant Quarantine and the Soil Conservation Service of the United States Department of Agriculture with the Texas Agricultural Experiment Station. They were made possible by the location, near Waco, Tex., of the Blacklands Experimental Watershed of the Hydrologic Division of the Soil Conservation Service. The field station is located 18 miles southeast of Waco, in the "Blacklands," which is typical of millions of acres of fertile cotton lands in central Texas. It is one of three similar hydrologic stations in the United States and the only one of its kind in the Cotton Belt.

PLAN OF OPERATION OF SOIL CONSERVATION SERVICE FIELD STATION.—The Soil Conservation Service project operates on a watershed of about 6,000 acres, but to have full control of all farm operations needed in connection with desired changes in land use and types of crops, and to be able to install all necessary measuring equipment for making comprehensive and detail hydrologic and land-use studies, the Service purchased several farms totaling 841 acres. These farms are contiguous and were selected so that the area is divided into two similar watersheds of approximately 300 acres each. It is planned that one of these watershed areas will be continued in prevailing farm practices throughout the life of the project, while the other area will be operated in prevailing practices until about 1942, when improved practices will be put into operation and continued throughout the remainder of the life of the project. In other words, each area is to be treated alike, or continued in the old practices, for approximately 5 years, and then one area, designated "Y," will be changed to the best known improved farm practices while the other area, designated "W," will remain under the old farming system or prevailing practices.

Under the prevailing practices, or old plan of farming, approximately 50 per cent of the total cultivated acreage will be planted to cotton, 25 per cent to corn, and 25 per cent to oats, sorghums, and other crops. Under the improved practices there will be a reduction in the amount of cotton and corn and an increase in the amount of pasture and other erosion-resistant crops, In addition, terracing, contour tillage, strip cropping, protection of drainage channels, and other conservation practices will be used as needed.

These two areas are subdivided into farm units, each unit representing all land farmed by an individual tenant. In most cases the tenants are the previous owners, who have been permitted to live in their former homes and continue farming the same land under certain conditions

stipulated by the Soil Conservation Service. The farms are further divided into fields and are so numbered on the land-use map. The farm unit and field numbers remain constant from year to year, but the crops in the different fields change to conform to the plan of rotation. There are four farm units, or tenants, in the "Y" area and five in the "W" area.

RECORDS MADE BY SOIL CONSERVATION SERVICE.—Each tenant is required to submit weekly reports of all farm operations performed. Certain farm operations may have a direct bearing on insect populations. Some of these may be listed as follows: Time of harvesting cotton, time and method of destruction of old cotton stalks, time and depth of fall plowing, method and time of cleaning fence rows and waste lands, time of planting cotton and other crops, varieties of cotton and other crops in crop rotations. Accurate yield records are kept for each field. A yearly land-use map is made by the Soil Conservation Service, showing field locations of each crop. This map also shows the row direction of each crop and acreage of each field. Maps have been made showing soil types, land slope, and erosion classification for each area.

Among several government-owned structures at the field headquarters are a meteorological building and an enclosed weather yard with the following equipment: An anemograph for recording wind velocity and direction and the duration of sunshine, a baragraph, a mercurial barometer, a hygrothermograph, a shelter psychrometer, a standard anemometer, and a low anemometer used in connection with three evaporation pans. In the field are located, at various points over the government-owned land, 3 sets of soil thermographs, 22 recording rain gages, 11 ground-water recorders, and 28 surface-runoff stations. On the remainder of the 6,000 acres the following additional equipment is in operation: 2 air thermographs, 79 standard rain gages, 13 recording rain gages, 3 ground-water recorders, 6 surface runoff stations, 2 field anemometers, and 4 maximum and minimum temperature stations.

All the above-enumerated records, as well as the results that will be obtained from the operation of the project as described above, are or will become available for use in connection with studies being made on this project of the activity, population, and damage of cotton insects.

SCOPE OF THE INSECT STUDIES.—Detailed seasonal-infestation records are being made of the following injurious insects on cotton in the Y and W areas of the Soil Conservation Service project: Cutworms, cotton aphid, thrips, cotton flea hopper, boll weevil, bollworm, cotton leaf worm, fall armyworm, and pentatomids. Records are made of any unusual outbreaks of other insects on cotton. Infestation records of corn ear worms on corn are also made, so that the abundance and seasonal activity of this insect on its different hosts can be traced.

While it would have been desirable to make insect-population studies in each of the approximately 36 fields of cotton in both areas, the inclusion of all these fields was impossible with the limited entomological personnel[1] assigned to the project. One-half of the cotton fields, or 9 from each area, are therefore under study each year. The fields planted to cotton necessarily vary from year to year as the plan of crop rotation is followed.

METHODS OF MAKING POPULATION COUNTS.—The methods of making the population counts or infestation records vary with the different species of insects, but they conform more or less to methods adopted by most cotton entomologists in determining populations in control and other types of field tests. The present method of sampling or making the infestation records on the different insects is as follows:

(1) *Cutworms* are usually the first injurious cotton insects to appear. In making infestation records of these insects 25 linear feet of row are inspected at 8 representative points in each field and the numbers of worms and row-feet injured are recorded.

(2) *Cotton aphid* infestation records are made by counting the aphids on 1 square inch of leaf area on each of 25 plants at each of 8 points in a field. During the pre-square stage of the plant the top leaf is examined, but later the fourth leaf from the top is used for the sample.

(3) *Thrips* population counts are started when the cotton reaches the four-leaf

[1] The senior author is assigned to this project permanently; two field assistants are assigned full time for approximately 3 months each summer and early in the season additional assistance is available from the regular personnel of the Waco laboratory.

stage and are made by pulling 20 plants at random in widely distributed areas over a field, placing them in Berlese funnels (Bondy 1940), and later counting the thrips that fall into vials of alcohol.

(4) *Cotton flea hopper* infestation records are begun when the cotton reaches approximately the four-leaf stage and are made by inspecting 25 main-stem terminal buds at each of 8 points in a field and counting the adults and nymphs present.

(5) *Boll weevil* infestation is determined by inspecting 25 squares at each of 8 points in a field and recording the numbers of punctured squares and adult weevils present. The record is started when the cotton averages approximately 5 squares per plant.

(6) *Bollworm* infestation records are made by (*a*) inspecting 25 main-stem terminal buds at each of 8 points in a field for the presence of eggs, and (*b*) inspecting 25 squares and 25 bolls at each of 8 points in a field and recording the injured forms. The time of starting bollworm infestation records varies from year to year, but is usually about 2 weeks after the first emergence holes appear in corn.

(7) *Pentatomid* populations are determined by making 25 sweeps, with a 16-inch-diameter sweeping net, at each of 4 points in a field and recording the number and stages of each species of pentatomid collected.

(8) *Cotton leaf worm.* General observations are made in each field as to the presence and abundance of this insect. Records are kept of the poison applications made or that should have been made by each farm-unit operator in order to keep the leaf worm under control during each season.

(9) *Fall armyworm.* General observations are made on the presence and abundance of armyworms in each field throughout the cotton-growing season.

(10) *Corn ear worm* infestation records are made on corn by inspecting 25 ears at each of 8 points in a field and counting the exit holes. The records are started about 2 weeks after corn begins to silk, or about the time the first exit holes appear. The cornfields inspected are adjoining or near the selected cotton fields.

As nearly as possible all records are made at regular weekly intervals and throughout the periods of injury or infestation of the different insects. This makes it necessary that some records, such as those made on cutworms and cotton aphids, be started early in the season, or during the first part of May, and that others, such as those made on the bollworm, the boll weevil, and the cotton flea hopper, be completed late in the season, or during the latter part of August.

In addition to the above-described records made in the Y and W areas, special attention is being given to strip cropping in relation to cotton flea hopper populations outside of the Y and W areas. Eight fields are selected for study each year. The fields are divided so that in one series the cotton is stripped with tall growing crops, such as corn, sorghum, etc., and in another series the cotton is stripped with low-growing crops, such as oats, clover, etc. Two fields in each series have rows running in the direction of the prevailing wind and two fields in each series have rows running crosswise to the direction of the prevailing wind. Each field has three strips or plots of cotton in which flea hopper infestation records are made at regular weekly intervals. The 2nd, 6th, 10th, and 14th rows from the outside toward the center of each strip of cotton are selected for the records. Twenty-five terminal buds at each of two points on the selected rows are inspected for flea hoppers.

RESULTS ANTICIPATED.—Only two seasons' studies of insect activities have been made, and no results or even trends are evident thus far. None were anticipated for 4 or 5 years, or until after the improved farm practices had been put into effect on one of the areas. At least 9 or 10 years will probably be required to complete the studies. The insect-population samples are being made so that it will be possible to compare and evaluate records made from year to year in each field, records made over a period of years in the two areas when treatments were alike, and records made in the two areas after improved farm practices had been put into operation in one of the areas. It is hoped that these studies will give definite information concerning insect damage to cotton with reference to soil-conservation practices.—3-12-41.

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The Effect of Host Density on the Rate of Reproduction of Entomophagous Parasites[1]

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The biological method of insect pest control is concerned with attempts to modify quantitative relations between the populations of an insect pest and its enemies and the space occupied. The method is still largely empirical, although in recent years considerable progress has been made toward the establishment of a scientific basis for biological control, through resort to both analytical theory and experimental research.

If a parasite species is to *regulate* the population density of its host, that is, if it is to hold the host population density within definite limits, avoiding either excessive increase or extermination, it must have the ability to destroy a greater fraction of the host population when the density of the latter is high than when it is low. If destruction were merely directly proportional to population density, the factor causing it would not be a regulatory one. The density at which the host population will be stabilized depends upon the rate at which host mortality increases with density, the population being stabilized of course when mortality and natality are of equal value.

This increase of mortality, in so far as it is caused exclusively by the interaction of a host population and a parasite population, comes about through the effect of host density on the fecundity (actual, not potential, fecundity) of the parasite. The conclusion *a priori* that the number of progeny left by a parasite would depend within broad limits upon the population density of the host seems quite safe, since obviously the number of progeny will depend upon how many hosts the parasite can find, and the number it can find certainly depends upon the density of the host population. This could be absolutely true of course only where the host density was such that the parasite could not find sufficient hosts for its entire egg supply during its lifetime. But though the effect of host density can thus be established by abstract reasoning, experimental evidence is desirable to support this conclusion, since the influence of host density on the rate of parasite reproduction represents one of the first principles of biological or natural control.

In a laboratory study of the possible effect of host density on the rate of reproduction of a parasite, two types of conditions must be distinguished. If the hosts are sufficiently close together, the *search* of the parasite for the host becomes a relatively unimportant matter; in fact, there is practically no searching. This point can be demonstrated by placing a group of dipterous puparia in a tube with their parasites. Under these conditions the number of progeny a parasite leaves in a given time depends almost entirely upon the rate at which it can produce eggs, provided the supply of puparia is ample. Here the rate of reproduction of the parasite is a function of host *numbers* and parasite egg-laying capacity. If, however, these puparia are widely separated or, for other reasons, are so difficult to find that the number of progeny left by the parasite bears some relation to the *distance separating* the hosts, then the factor of *searching* enters, and the rate of reproduction becomes a function of host *density* and parasite searching capacity.

The necessity for searching actually exists in nature in most cases. It is impor-

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tant to recognize the difference between searching and nonsearching. This distinction has sometimes been overlooked in experimental work. The factor of *searching* is of paramount importance in relation to natural control (Smith 1939).[4] Consequently, to investigate the quantitive aspects of this question, the experiment must be set up in such a way as to cause the parasitees to *search* for their hosts.

Puparia of the common housefly, *Musca domestica* L., were used as hosts, and the two common puparial parasites, *Mormoniella vitripennis* (Walker) and *Muscidifurax raptor* Gir., served as parasites. In order to study the searching ability of a parasite and thus the effect of host density on the parasite's reproductive rate, the host density must be artificially arranged in such a way that the parasite's ability to find hosts is reduced. Otherwise, the experimental setup would have to be so large as to be unwieldy.

Various methods of causing the parasite to search for the host were tried before one was chosen. That finally adopted consisted of the use of clean barley in a tight-lidded ten-gallon tin with the puparia dispersed therein at random. Barley was found to be the best medium because it is fairly close to a fly puparium in density and somewhat larger. Consequently, after a test has been run, the puparia can be conveniently screened out. The light-proof container eliminates the factor of phototropism. The puparia necessary to attain the required host population density were thoroughly mixed with two quarts of barley in the bottom of the container; then an additional quart of barley was spread over the surface to hide any puparia close to the top. The desired number of parasites was added, and the cover was closed and sealed with adhesive tape.

The tests were run at a constant temperature of 80° F., and all puparia were large, well formed, uniform in size (since various authors have shown that host size influences host selection), and three days old. The parasites used were all four days old, were previously fed honey, and had not been allowed to oviposit. The length of time the parasites were permitted to search for hosts was, uniformly, 24 hours.

A density of 40 parasites was chosen as a constant for all tests, and the density of hosts was varied from 1 to 300. Thus, in each case, 40 parasites searched through three quarts of barley for hosts varying in population density from 1 to 300. Any other densities could have been employed but the generalizations established would be found to be essentially the same in all.

The two parasite species, *Mormoniella vitripennis* and *Muscidifurax raptor*, used in this phase of the investigation, differ in their ability to find hosts. Individuals of *Mormoniella* must search diligently in order to find hosts in the universe described. On the other hand, *Muscidifurax* is apparently very strongly attracted to its host, that is, this parasite apparently proceeds directly to the host puparium. A comparison of the data from these tests shows very striking differences in the searching capacity of the two species of parasites. For this reason, the results from the two experiments are presented and discussed separately.

SEARCHING ABILITY OF MORMONIELLA.—Observation and experience have long indicated that density of the prey or host is an important factor governing the reproduction of a predator or parasite, and that within certain limits, the higher the density of the host, the greater the rate of reproduction of the entomophagus insect feeding upon it. Flanders (1935) has presented experimental evidence in support of this. The exact quantitative relations, however, have not in general been demonstrated heretofore.

Volterra (1926) assumes that the coefficients of increase and decrease of the predator are linear in relation to population density of prey, and bases this assumption upon the principle of encounters. On the other hand, Gause (1934) assumes a nonlinear relation between relative increase of the predator and concentration of the prey. He writes as follows:

> The simplest assumption would be that the geometric increase in the number of predators is realized in direct proportion to the number of prey. . . . But experience shows the following: If we study the influence of the increase in the number of the prey per unit of volume upon the increase from one predator per unit of time, we will find that this increase rises at first rapidly and then slowly, approaching a certain fixed value. A further change in density of the prey does not call forth any rise in the increase per predator. In the limits which interest us we can express this relationship with the aid of a curve rapidly increasing at first and then approaching a certain asymptote. . . . The curve connecting the relative

[4] For valuable discussions of this subject see, among others, Nicholson (1933), Laing (1937), Walker (1937), and Thompson (1939).

increase of the predators with the concentration of the prey can be expressed by the equation:

$$y = a(1 - e^{-kx}).$$

The results of our tests upon the effect of host density on increase of *Mormoniella* are presented in table 1. These data are represented graphically in figure 1 and are seen to agree closely with the curve described by Gause.

Gause's experimental verification of this curve is based on results of experiments by Smirnov and Wladimirov (1934), who used *Mormoniella vitripennis* and the pupae of the fly *Phormia*. However, it must be noted that their experiments were conducted by introducing one pair of parasites each into test tubes containing varying numbers of hosts and, as a result of the very limited universe employed, real searching was not involved. Although their data appear to follow a curve such as that described by Gause, close examination of the figures indicates that the results can be represented just as well at the lower densities by a straight-line relation between density of host and increase of the parasite. Later the rate of increase rapidly curves off, probably because of exhaustion of the egg supply of the single female parasite used.

Table 1.—Results of search by 40 parasites (*Mormoniella vitripennis*) for hosts in varying densities, distributed through three quarts of barley (24-hour period).

	Host Population Density						
	1	5	25	50	100	200	300
Replication	Number of hosts discovered per individual test						
A	1	4	20	31	50	47	71
B	1	5	17	32	44	64	65
C	0	3	16	33	53	49	50
D	1	1	20	30	46	57	
E	1	5	18				
F	1	3	12				
G	1	5	20				
H	1						
I	1						
Total number of hosts discovered	8	28	123	126	193	217	186
Average number of hosts discovered[1]	0.89	4.00	17.57	31.50	48.25	54.25	62.00

[1] Parasite increase shown in figure 1.

Nevertheless, the curve and formula given by Gause actually describe the effect of host density on the reproduction of parasites under conditions where real searching occurs, as is amply borne out by the present results. The curve in figure 1 shows the relation between host density and reproduction per parasite. As host density increases, the total number of hosts discovered increases (represented as parasite increase in figure 1), causing the curve to rise rapidly at first and then more slowly, approaching a certain fixed value asymptotically. This curve can be expressed by the equation $y = a(1 - e^{-kx})$, where y = parasite increase (in terms of number of hosts discovered); a = limit approached asymptotically by y; e = base of natural logarithms; k = a constant determining the rate at which the change of y with host density decelerates; and x = host density.

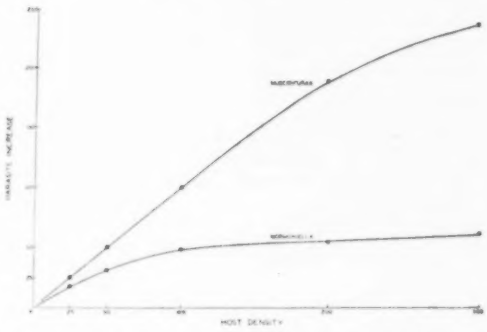

FIG. 1.—Relation between population density of the host, *Musca domestica*, and increase of the two parasites *Muscidifurax raptor* and *Mormoniella vitripennis*.

The number of hosts discovered (table 1) is the most practical measure of the searching ability of the parasites used in this study, and for purposes of simplification, this number is utilized as a measure of parasite reproduction, with the assumption that each host discovered is oviposited in and produces a parasite. This value is determined by dissection of the fly puparia in order to find which ones have been oviposited in or stung and which may have died from other causes, the adult failing to emerge.

Gause made no attempt to explain why such a curve should be obtained instead of a linear relation. The reasons for this curvilinear relation, of course, are more difficult to determine than are the actual relations; but the reasons are important, both practically and ecologically. Science ultimately seeks to know *why*, and practical considerations require that the factors determining population densities be

known in order that field populations of animals may be better understood and controlled by man.

Why, in the present case (Fig. 1), the trend falls off instead of continuing as a straight line has not yet been determined experimentally. The most likely explanation seems to be that it is due, partially at least, to the fact that *Mormoniella* spends considerable time, sometimes as much as 6 to 8 hours, on each host it discovers. This time is spent in investigating

Table 2.—Results of search by 40 parasites (*Muscidifurax raptor*) for hosts in varying densities, distributed through three quarts of barley (24-hour period).

	Host Population Density					
	5	25	50	100	200	300
	Number of hosts discovered per individual test					
A	5	25	50	100	195	245
B	5	25	50	100	184	233
C	5	25	50	100	189	239
Total number hosts discovered	15	75	150	300	568	717
Average number of hosts discovered[1]	5	25	50	100	189.33	239

[1] Parasite increase shown in figure 1.

the host, in ovipositing, in feeding, and finally (most of the time), in apparent rest on the host. In fact, a greater part of the 24 hours is spent in activities other than actual searching. Therefore, the greater the host density, the smaller the fraction of the 24 hours of "generation" time spent in actual searching for additional hosts.

While the results of this experiment appear to contradict Volterra's premise that the rate of reproduction of a parasite individual is directly proportional to host density, it would be a mistake to conclude on these grounds alone that Volterra was wrong. Volterra was considering the continuing effect of a parasite population on a host population, not a single discrete generation with a given number of parasites, as in this experiment. The point illustrated by this experiment is that the reproductive rate of a given number of parasites acting for a given time, bears a certain curvilinear relation to host density. It is plain that in the next parasite generation, owing to the fact that there would be many more parasites, the total reproduction of the parasite population would be much greater than in the first generation if the host supply is still ample. Therefore, there is nothing in this experiment nor in the one cited by Gause, to disprove Volterra's assumption, although it may be criticized for other reasons.

Searching Ability of *Muscidifurax*.—Tests were conducted with *Muscidifurax raptor* in exactly the same kind of experimental universe and under conditions similar to those used with *Mormoniella*. Results parallel those of the previous tests and should be compared with them.

The population figures used throughout this discussion represent host *density*, not *number*, since the host population is distributed through a constant volume of barley. However, *Muscidifurax* is so strongly attracted to the hosts that its searching is particularly efficient, the effect being the same as if the hosts alone were put in a vial with *Muscidifurax*.

Here parasite reproduction (parasite increase, figure 1, average number of hosts discovered, table 2) is seen to be directly proportional to host "density"; in fact at the lower densities all the hosts are "stung" which is not the case with *Mormoniella*. Clearly this graph indicates the superiority of the parasite's searching capacity over that of *Mormoniella*.

Although the egg-laying capacity of the two parasites has not yet been determined it seems probable that neither is parasitizing hosts to the limit of its egg-laying capacity. The limiting factor is the ability of the parasites to discover hosts relative to the host population density and it is evident therefore that searching capacity, not potential reproductive capacity, determines the relative efficiency of the two species. Since the efficiency of a parasite species would be measured by the host density at which it, together with the other environmental factors, could prevent from maturing all but a number of host progeny equal to the host parents, and since under the conditions of the experiment, *Muscidifurax* finds, at a much lower host density, numbers of hosts equivalent to those found by *Mormoniella* it would be rated as a more efficient species.

Summary.—It is pointed out that if entomophagous parasites are to regulate the population densities of their hosts, they

must be able to destroy a greater fraction of the host population when it is dense than when it is sparse. Experimental evidence bearing on the exact relation between host density and parasite reproduction is desirable but is almost entirely lacking. Host density affects the parasite's rate of reproduction through its relation to the success of the parasite in finding hosts. The parasite's ability to find hosts, other things being equal, is a specific characteristic.

Using housefly puparia distributed at random in a container filled with barley, the success of two species of parasites, *Mormoniella vitripennis* and *Muscidifurax raptor*, in searching for hosts, was investigated. It was demonstrated that *Mormoniella* found hosts at a rate which increased with increasing host density, but which was not constant and which finally approached a fixed rate asymptotically. This deceleration of the rate at which discovery increased with host density appeared to be caused by the increasingly greater proportion of time spent in nonsearching activities as the host density increased. These nonsearching activities are mainly oviposition, feeding, and resting. *Muscidifurax* has such great searching ability in comparison with *Mormoniella* that under the conditions of the experiment, all the hosts were found at the lower densities. These experiments were restricted to single "generations" and a constant parasite density.

The experiment is considered to illustrate the importance of searching capacity, as opposed to potential reproductive capacity, in the determination of a parasite's efficiency.

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The Citrus Bud Mite, *Eriophyes sheldoni* Ewing[1]

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The citrus bud mite, *Eriophyes sheldoni* Ewing, was first recognized by J. R. La Follette and H. B. Sheldon on June 17, 1937, on lemon trees near Santa Paula, Ventura County, California. They observed an unknown Eriophyid mite infesting the buds of lemon trees and associated the presence of this mite with certain characteristic abnormalities of foliage and fruit growth, the nature of which had not been previously understood. A portion of a particular planting of lemon trees, that was seriously affected with what is now recognized as a heavy infestation of this mite, was treated by H. B. Sheldon in May, 1937, with a zinc preparation that contained sulfur. The treated trees responded with a flush of normal new growth, thus indicating the possibility that the sulfur afforded a measure of control of the causative agent, since previous treatments with zinc, copper, magnesium, manganese, and other elements used without sulfur did not re-

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sult in favorable tree response. Further observations at that time and extensive studies subsequently have clearly demonstrated that this mite is responsible for the abnormal growth characteristics as originally believed by La Follette and Sheldon. The mite proved to be an undescribed Eriophyid and was later named *Eriophyes sheldoni* by H. E. Ewing.

The origin of this mite and the length of time that it has existed in California

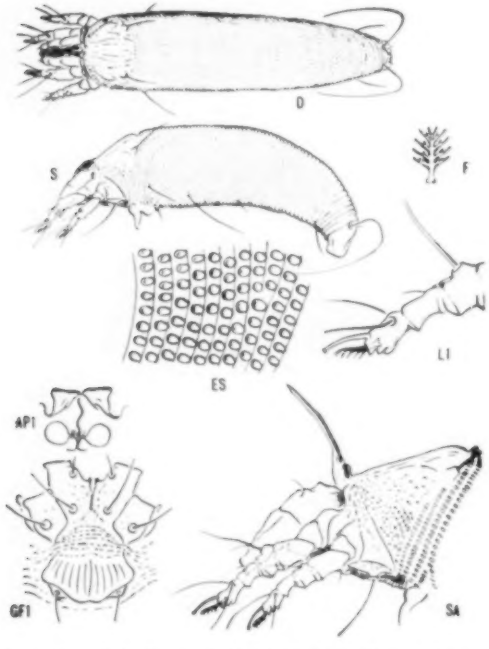

FIG. 1.—*Eriophyes sheldoni* Ewing. From Santa Paula material. Drawings by H. H. Keifer. Legend: API—internal female genitalia, D—dorsal view of mite, ES—detail of side skin, F—featherclaw, GF1—female genitalia and coxae from below, L1—left foreleg, S—side view of mite, SA—side view of anterior section of mite.

are unknown. Pioneer citrus growers in the Santa Paula area report that they have observed abnormal fruits such as are now recognized as symptomatic evidence of infestation at various times during the past twenty years. The widespread distribution of the mite in southern California is further eivdence to indicate that it has been present in the state for many years.

When the citrus bud mite was first recognized in the Santa Paula area and surveys by various agencies began, plantings in canyons, on higher sloping ground, or areas adjoining the uncultivated foothills were found to be more heavily infested than elsewhere. Plantings that had not received pest control treatments for several years or had not been treated annually also had heavier infestations. Furthermore, it was observed that characteristic symptoms of injury by this mite were seldom found in abundance on growth that was more than two years old, even where no pest control treatments had been applied for several years. Within three years after this mite was first recognized it was present in relatively heavy populations in most lemon groves in Ventura County, an area which has a range of climatic conditions extending from the warmer intermediate to the cooler coastal areas. Since 1939 the mite populations have built up extensively in most lemon areas of Santa Barbara County.

At the outset, the mite was found occasionally on Valencia oranges; however, as yet it has not become of importance. It is of interest to note that the first infestations on oranges, as with lemons, were found in plantings either on higher sloping ground, in canyons, or adjoining uncultivated foothills.

After a preliminary account of the existence of this Eriophyid in California was published (Boyce & Maxwell, 1938), it was found in Australia. Specimens were obtained from P. C. Hely of the Department of Agriculture, Narara, New South Wales. Hely (1939) states "Bunched growth and shoot contortion in citrus trees have been observed for some years in this state, and, following on the discovery in California of a small mite infesting buds of trees showing such bunchiness, similar mites were found here in March, 1938. Mites have been found associated with this bunched condition in most citrus areas here, both coastal and inland, and injury has been recorded on most of the common citrus varieties."

During 1939, R. J. Benton, of New South Wales observed symptoms typical of injury by this mite on mandarin orange in Honululu, Hawaii. Specimens of the mite were obtained through the courtesy of F. G. Holdaway of the University of Hawaii.

The mites from Australia and Hawaii have been studied by H. H. Keifer of the California State Department of Agriculture, who considers them to be variations of *Eriophyes sheldoni* Ewing (in correspondence July 8, 1941).

Common Name.—The common name, citrus bud mite, was tentatively used to designate this mite by Boyce & Maxwell (1938). This common name is yet appropriate for the following reasons: (1) *Citrus* is the only known host; (2) this is apparently the first record of mite injury within the buds of *Citrus;* (3) the principal type of injury caused by this mite is the result of its habitation of the buds; and (4) the mite is well known locally by entomologists, growers, pest control operators, and others as the citrus bud mite.

DESCRIPTION OF STAGES: ADULT.—As previously indicated, the mite was described as *Eriophyes sheldoni* by Ewing (1937). Subsequently, the systematics of this species have been very extensively studied by Keifer (1938) in connection with his monumental work on the taxonomy of the Eriophyidae. Keifer's illustrations are shown in figure 1, and his description is as follows:

> Female spindle-form, yellow to orange in color, 170 to 180μ long, 35 to 42μ wide. Rostrum 21μ long, projecting down. Shield gently curved above, 23μ long, 21μ wide; design usually indistinct in disc, of three principal longitudinal lines, the central broken and anchor-shaped caudad, the sides of the disc with curved lines or lines of dots, side of shield with curved lines and band of granulations along rim; dorsal tubercles 17μ apart, on rear rim, the seta 16μ long and projecting backward. Legs of moderate length. Foreleg 24μ long, patella 4.5μ long, tibia 5.5μ long, patellar seta 18μ long; claw gently bent down, knobbed, 4.5μ long, featherclaw 5-rayed. Hindlegs 21.5μ long; patella 4μ long, tibia 4.5μ long, patellar seta 9μ long; claw 5.5μ long. Sternum indistinctly forked; seta of second coxa 29μ long. Abdomen with about 65 to 70 rings, considerable ventrad reduction in ring number in some individuals; the rings 2μ wide, strongly microtuberculate, the microtubercles about touching the rear rim of the rings; the last several rings microstriate. Lateral seta 19μ long, above and behind genital seta, about ring 8–10. First ventral seta 30μ long, on about ring 23–25. Second ventral 8.5μ long, about ring 34–37. Third ventral 16.5μ long, 5 or 6 rings from rear. Caudal seta 40 to 45μ long, accessory seta 3.5μ long. Female genitalia subcordate, 12μ long, 19μ wide, coverflap longitudinally furrowed, 8–10 furrows; glands oval, short-stalked; seta 10.5μ long.
>
> Male 120 to 130μ long, 27.5μ wide. Genitalia 11μ long, 13.5μ wide; seta 7μ long.

The following excerpts are from Keifer's comments regarding this species. "The Santa Paula specimens which are in the type locality show a considerable reduction in ring number from the dorsal to the ventral sides. They also as a rule do not show so distinct a shield pattern as the Orange County individuals. The shield pattern seems rather variable throughout the range of the mite. . . . Recognition characters: size, shield design, 5-rayed featherclaw, host. This is one of the smaller Eriophyids to be met with in California."

There is a certain amount of morphological variation in the mites from different localities. However, there is one form which is orange or pinkish in color found in all localities. Very little is known about this form, except that it is apparently not limited to one sex and its occurrence is not related to any particular season of the year.

Egg.—The egg is somewhat translucent or whitish, nearly hyaline. It is almost spherical in shape and averages 48 microns in length by 33 microns in width.

Larva.—The newly hatched larva is somewhat triangular in shape. The cephalothorax is greatly out of proportion to the remainder of the body. There are about 52 dorsal and 32 ventral striations on the abdomen. The body length of the mature larva is approximately 100 microns.

Moult I: During this quiescent period the larva moults and the nymph may be observed within the larval cuticle which has been enlarged.

Nymph: The nymph is similar to the adult in shape, although it is somewhat smaller and the genital organs are not evident externally. The body length of the mature nymph is approximately 130 microns. There are about 65 dorsal and 46 ventral striations on the abdomen.

Moult II: The nymph moults during this quiescent period and the genital organs of the adult become apparent externally.

DISTRIBUTION.—While the origin of this mite is unknown, it appears probable that the species is indigenous to regions where *Citrus* is native and that it was introduced into this country on some species or variety of *Citrus.* In the United States the mite has been recorded only from California. It has been found only in the southern portion of this state, in the following counties: Santa Barbara, Ventura, Los Angeles, Orange and San Diego. It is generally distributed on lemons in all of these counties, except Los Angeles, in which only light infestations have been found in several localities. An explanation of the latter condition together with the fact that the mite is not economically important in Orange and San Diego coun-

ties and that it has not been found in either San Bernardino or Riverside counties, affords an interesting basis for conjecture.

This species also occurs in Queensland (Hely, in correspondence May 8, 1940) and New South Wales, Australia, and on the Island of Oahu, Hawaii.

FIG. 2.—Leaf-axil bud of lemon with leaf removed showing citrus bud mites infesting bud in the area in which petiole of leaf oppresses the bud.

Nursery stock, including seedlings for budding and bud wood is probably the most general medium of disseminating the mite into uninfested areas. The mites are disseminated locally by wind, as evidenced by the fact that they have been collected on glass plates coated with a sticky substance placed within and near infested plantings. It is probable that insects such as honeybees, ants, thrips and spiders, and perhaps birds, may disseminate these mites.

HOSTS.—*Citrus* species are the only known hosts. At frequent intervals since this mite was first found in the Santa Paula area, intensive surveys by many individuals have been made without finding it on any plant except *Citrus*. The mite has been found developing on all species and varieties of *Citrus* grown in Santa Barbara and Ventura counties, including lemons, limes, oranges, grapefruit and miscellaneous varieties. In this state the lemon is the preferred host.

NATURE OF INJURY AND ECONOMIC IMPORTANCE.—The principal type of injury is caused by the mite feeding within the leaf-axil buds (Fig. 2) in which from a few to 50 mites and eggs are commonly found and as many as 300 have been noted in an individual bud. The bud scales are blackened and often the entire bud is destroyed. More commonly, however, small adventitious buds develop which are subsequently blasted. Thus, extensive multiple budding occurs (Fig. 3) resulting either in no further production of twigs or blossoms, or in an inferior type of growth. A relatively small amount of injury within a bud results in a delay of the development of the twig or blossoms, and when they do develop they are usually deformed. The twigs that develop from injured buds may be normal in shape but shortened, or

FIG. 3.—Excessive multiple budding on lemon caused by the citrus bud mite.

they may be thickened or flattened, or both, and also twisted and greatly contorted (Fig. 4). Several twigs may develop from the multiple buds resulting in a rosetted type of growth. The terminal growth, particularly on young, vigorous trees is commonly of a bunchy type with deformed stems and leaves (Fig. 5). The leaves that develop from infested buds assume curious and irregular shapes (Fig. 6). Some are constricted near the midsection, in others the midrib is divided, while others are curled, twisted or stunted. In very heavy insfestations that have existed for many months more than 95 per cent of the buds on the tree may be infested.

Blossoms developing from infested buds are frequently malformed, some with curling at the base, some with certain flower parts stunted and mis-shapen or aborted

FIG. 4.—Lemon twigs deformed by the citrus bud mite.

(Fig. 7). Fruits developing from such flowers are usually of irregular and often grotesque shapes (Fig. 8). It is not uncommon for the percentage of deformed blossoms to exceed 50 per cent of the total. Most of the fruits that are greatly deformed drop off before they attain much size.

From the above description of the effect of the mites in causing abnormalities in twig, leaf, blossom, and fruit development, it is evident that the organization

FIG. 5.—Bunchy type of terminal growth showing deformed twigs and leaves on lemon tree infested with the citrus bud mite.

FIG. 6.—Deformed lemon leaves which developed from buds infested with the citrus bud mite.

within the affected tissues is greatly disrupted. Whether or not this is caused by the direct physical action of the mouthparts of the mite in obtaining food or by chemical means, due to a material secreted by the mite, is a point of considerable interest.

The mites also occur beneath the button, which is the calyx and receptacle of the fruit, and they feed on both the tissue of the fruit and the button. Consequently, the area of the fruit beneath the button on which the mites feed assumes a black color, and when large numbers of mites are present the entire area beneath the

FIG. 7.—Deformity of lemon blossoms and young fruits caused by the citrus bud mite.

button is black (Fig. 9). Several hundred mites and eggs are commonly present and as many as 1,000 have been observed beneath an individual button. In very heavy infestations most of the fruits on the tree that are half grown or larger may be infested. However, this type of injury has not assumed economic importance up to the present time.

Occasionally the mites have been found on the rind of green lemons at the points of contact made by lemons growing in tight clusters. The tissue of the rind on which the mites feed becomes dark in color. This type of injury has not been abundant enough to be of importance.

In this state the lemon is the only host in fruiting that is seriously affected. Approximately 25,000 acres of lemons are infested. The mite may be considered of economic importance on a total of about 20,000 acres, most of which are in the coastal and intermediate areas. General observations indicate that the Lisbon lemon is not as seriously affected as is the Eureka. However, a preliminary census of mite populations and foliage-injury ratings on these two varieties growing in the same orchard indicates no significant difference in their susceptibility to injury.

FIG. 8.—Malformed lemon fruits which developed from blossoms injured by the citrus bud mite.

The Valencia is practically the only variety of orange grown in the areas where the mite is of most importance on lemons. The acreage of oranges infested by this mite and the degree of infestation has increased within the past two years. The characteristic symptoms of injury on oranges are similar to those on lemons, although in general they are not so pronounced, except in the deformity of the pedicel of the blossom. The pedicel of the blossom on oranges is characteristically elongated, flattened, ribbed or crooked, or has various combinations of these symptoms, while on lemons it is usually not so greatly deformed.

Injury of economic importance on bearing lime, grapefruit, and miscellaneous varieties of *Citrus* in infested areas has not been observed. Under conditions of moderate to heavy infestations of this mite, seed bed stock of all varieties being grown for budding is seriously affected. Similarly, budded nursery trees, both lemon and orange, and young trees set into the orchard are seriously injured. However, lemon nursery stock and young orchard trees are apparently more seriously injured than orange trees under the same conditions. A newly planted tree that is heavily infested may either be greatly restricted in growth or may produce a malformed, undesirable type of growth.

In Australia the characteristic injury on oranges caused by this mite is apparently somewhat different from that in this state; bunched growth and shoot contortion are apparently more pronounced and more injurious there. Regarding this matter, Hely (in correspondence May 27, 1941) states, "Injury has been recorded on most of the common citrus varieties including navels, lemons, valencia, sevilles, joppas, mandarins, Parramatta seedling, grapefruit and shaddock. In the coastal districts, navels and silettas are the most commonly infested and, except in a few cases, are the only varieties on which injury is thought to be of much importance. Lemons are generally, but not heavily, infested on the coast, although in inland areas, this pest is confined almost exclusively to lemons and even navels immediately adjacent to heavily infested lemons, in these latter districts, usually show no sign of mite attack. . . . This injury consists largely in shoot contortion resulting in twisted wood, bunched growth and the production of numbers of weak shoots. No appreciable amount of deformed blossoms has been observed, nor has there been any effect on fruits."

The economic importance of the citrus bud mite on bearing lemon trees in California has not been determined quantitatively. Production records over a period of years, noting the quantity and quality

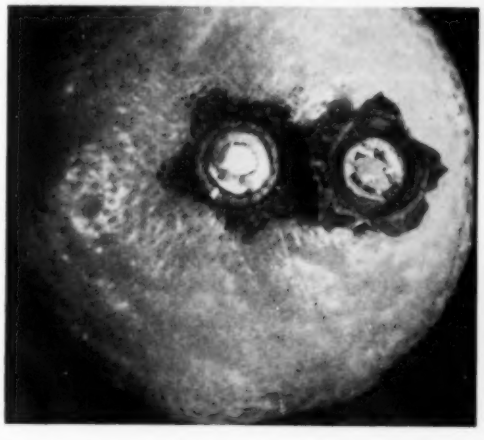

FIG. 9.—Mature lemon fruit with removed button at right showing blackened area on rind and on underside of button caused by feeding of citrus bud mites.

of fruits produced, are necessary for a satisfactory evaluation of this aspect of the problem. Extensive data show that when moderate to heavy infestations of this mite exist for a few months there is an extensive retardation and reduction in the quantity and quality of growth produced by the tree with the resultant decrease of tree vigor. Furthermore, there is a reduction in the quantity of normal blossoms which, under certain conditions, may result in a sparse lemon crop that contains a high percentage of abnormally shaped fruits.

LIFE HISTORY AND HABITS.—The eggs of the citrus bud mite are deposited singly, or in groups of from two to five or more, at random wherever the adults are feeding. This is always in a protected place within the buds, in the region where the petiole of the leaf oppresses the bud, among the tender young tissues of a bud that has just begun to elongate, within a developing blossom, or beneath the button of a fruit. The eggs, which adhere tenaciously to the plant tissue, are relatively more

abundant on the tender new growth of expanding buds than elsewhere.

The development of the mite varies with prevailing temperature conditions. Under field conditions during the autumn season the minimum time required for total development, that is, egg to adult, was 15 days and was distributed as follows:

Incubation of egg	3 days
Larval instar	4 days
Moult I	2 days
Nymphal instar	4 days
Moult II	2 days

Studies conducted during the warmer portion of the year showed the minimum developmental period from egg to adult to be 10 days. Under laboratory conditions at a nearly constant temperature of 75° F. the minimum total developmental period was 7 days. There was no measureable difference in the rate of development between males and females.

Females have not been observed to deposit eggs in less than 2 days after becoming adults. The number of eggs deposited per female is unknown. One group of 19 adults, in which the sexes were not differentiated, laid an average of 11 eggs each during a period of 8 days under laboratory conditions. Under similar conditions adults have survived for 31 days on the host and for 4 days on glass slides without food.

Data were taken at intervals of 14 days throughout the year, from August, 1939 to August, 1940, regarding the sex ratio of the mite population in leaf-axil buds and also beneath the buttons of lemon fruits. The average sex ratio of the mites beneath the buttons was approximately 1 male to 2.5 females, and this ratio was fairly constant throughout the year. However, the ratio in the buds varied considerably. The average ratio for this 1-year period was 1 male to 5.4 females and was greatest in December when the ratio was 1 male to 20 females and lowest in August when it was 1 male to 2.3 females.

The mites are seldom observed exposed. They infest all ages of buds on the tree and are commonly found deep within dormant buds on old wood that is several inches in diameter. The buds on the new twigs are infested almost as soon as they develop and the young lemon fruits are infested beneath the buttons as soon as they are large enough for the outer edges of the button to come in contact with the fruit and thus provide a protected location. From the foregoing it is evident that the mites migrate on the tree to a certain extent and that, instead of living superficially on the exposed portions of the tree, they inhabit a micro-environment which affords considerable protection against the elements. However, abnormally high temperatures are apparently destructive to this mite, since mortalities as high as 50 per cent have been recorded following temperatures above 110° F. in certain localized areas. Concerning this matter in Australia, Hely states (in correspondence May 27, 1941) "Owing to very high temperatures which occurred on 14th. January, 1939, however, an apparently conplete destruction of mites and eggs took place and further developments in these experiments were curtailed. The extent of the mortality induced by these severe conditions may be judged from the fact that even 12 months later, no mites or damaged buds could be found on trees known to have been previously heavily infested. It is of interest to note that temperatures, up to 112° F., which were experienced early in January, 1939, did not appear to affect mites adversely, but, when the temperature reached 118° F., however, with a correspondingly low humidity, the mortality was rapid and complete. . . . Some small increase in mite injury has again been observed during the past year but in no instance has any severe contortion been seen, and it is thought that probably this trouble will occur noticeably only in certain seasons. It has been frequently observed that, even on trees which show much contorted growth and where no treatments have been applied, that, for no apparent reason, subsequent growth flushes are quite normal."

The seasonal history of this mite has been given considerable attention. While the mite develops continuously throughout the year, it is significant to note that during each of the past three years the percentage of infested buds has increased from low levels to exceedingly high levels at a rapid rate during June and July. Since prevailing temperature and humidity conditions were not of such nature that higher rates of development would be expected during June and July than would occur

during August and September, this fact possibly indicates that there is a general migration of mites on the tree at this particular time of year.

CONTROL.—Studies of the control of the citrus bud mite have been very extensive during the past three years and have involved the use of hundreds of materials and combinations of materials in both the laboratory and field. Owing to the very small size of the mite, the checking of results of treatments for control is tedious and time-consuming. However, a satisfactory field-sampling method was developed for estimating population levels of the mites in the buds and also beneath the buttons of the fruits. This consists of an examination of a total of 600 buds and 120 fruits from each plot. Fifteen terminals of the same growth cycle and 15 fruits of approximately the same age and size are collected from each of 8 data trees in the central portion of a plot that is approximately 10 trees square. In the laboratory each bud is dissected, and the button is removed from each fruit, using a small lancet-pointed scalpel, while observations are made with a binocular microscope at a magnification of 30 diameters. Originally, the mites and eggs present in each bud and beneath the button of each fruit were counted. However, it was found after considerable experience, that the population of mites in each location could be estimated satisfactorily. After an extensive quantity of data had been accumulated and studied, it was found that the percentage of infested buds and fruits was the most satisfactory criterion for the estimation of the status of the population. The results of treatments are judged principally on the basis of a population census taken just prior to treatment and at appropriate intervals following treatment.

It has been found that the mites and eggs are susceptible to many materials. However, owing to the fact that the mites inhabit such protected locations, the only materials likely to be highly effective are those that penetrate in sufficient quantity, either in a liquid or gaseous state, to contact and kill the mites and eggs. In fact, no materials have been found that are consistently effective in destroying the mites and eggs beneath the buttons of fruits, in the dormant buds on the branches, and in the blossoms.

HCN fumigation, as practiced for control of scale insects infesting citrus, is not consistently effective enough in the control of this mite to be economically feasible. Fumigation with vaporized nicotine, employing high dosages under tented trees, while fairly effective in certain tests, was not generally effective enough to warrant extensive consideration. The regular petroleum oil that is used on citrus and sulfur or sulfur-containing materials applied as sprays have shown the greatest effectiveness of the various materials tested. For economic reasons, treatment for the control of this mite during the spring season should also control the citrus red mite, *Paratetranychus citri* McG., and that during the summer and fall should also control the black scale, *Saissetia oleae* Bern., and the citrus red mite. The regular oil spray (light-medium or medium grade petroleum oil used at 1.67 to 2 per cent) affords the most generally satisfactory control of the citrus bud mite as well as the citrus red mite and the black scale. Sulfur and sulfur-containing materials applied as sprays are effective in control of the citrus bud mite but such materials, that is, lime-sulfur, ammonium polysulfide, and wettable sulfur are not very effective in control of the citrus red mite and are of but little value in black scale control. Furthermore, all sulfur-containing materials used are hazardous to the fruit and foliage under conditions of high temperature. Ammonium polysulfide is significantly more safe under such conditions than is lime-sulfur or wettable sulfur. When 0.33 per cent petroleum oil is combined with ammonium polysulfide, the effectiveness in control of the citrus red mite is greatly increased. This combination, that is, ammonium polysulfide at 1.5 per cent, plus light-medium oil at 0.33 per cent, plus 2 ounces casein per 100 gallons has been rather generally used in spring treatments for the control of the citrus bud mite and the citrus red mite.

A so-called "inverted" oil-sulfur mixture consisting of 0.5 per cent light-medium emulsive oil, plus 4 pounds of 325-mesh sulfur, plus a stabilizer consisting of 0.25 to 0.5 ounce of blood albumin per 100 gallons has been found to be slightly more effective in control of the citrus bud mite and nearly as effective on the citrus red mite as the usual dosage of oil spray (1.67 per cent). However, this mixture is haz-

ardous under conditions of high temperature and for this reason may be useful only during the winter and early spring. It is relatively inexpensive and can be applied to trees laden with mature lemons without any measurable effect on the curing or handling of the fruit in the packing-house, in contrast to the results with the usual dosage of oil spray.

The low dosage oil sprays (0.75 per cent light-medium oil) in combination with powdered rotenone-bearing roots, are only fairly effective in the control of either citrus bud mite or citrus red mite, although they are satisfactory in black scale control. Nevertheless, these mixtures are less objectionable from the standpoint of fruit production and packing-house handling than the regular dosage of oil spray and are therefore widely used. Numerous preparations have been used in which derris extractives were solubilized with petroleum oil employing various mutual solvents. In the control of the citrus bud mite none of these mixtures has been consistently superior to those preparations in which the powdered rotenone-bearing roots have been employed.

Aqueous solutions of various organic compounds have been tested with many wetting, spreading and penetrating agents. Of these, the triethanolamine salt of 2-4-dinitro-6-cyclohexylphenol, used at a dosage of 0.025 per cent of the parent phenol in combination with one of several proprietary wetting agents, has shown most promise in preliminary tests for control of both the citrus bud mite and the citrus red mite.

Present indications are that two treatments with any of the materials now available may be required annually in many of the infested areas effectively to control the citrus bud mite.

Regarding the control of this mite in Australia, Hely states (in correspondence May 27, 1941) "Control experiments, commenced on navels, at Gosford, in the winter of 1938, indicated that both lime-sulfur and white oil are quite toxic to these mites. Either material, applied at 1 gallon to 40, in April, gave a substantial measure of control though best results followed the application of lime-sulfur, at 1:15, in June or July. Evidence of very satisfactory control was still apparent the following January."

NATURAL ENEMIES.—Several predaceous species of Arthropods are commonly found among colonies of the citrus bud mite. They are the black hunter thrips, *Leptothrips mali* (Fitch), a Cecidomyid, *Arthrocnodax* sp., the mites *Seilus* sp., and *Cheletominus ornatus* Berlese. In no instance have general observations indicated that these predators were of material importance in either reducing or limiting the populations of this Eriophyid. Several other species of mites of unknown habits are also commonly found associated with the citrus bud mite.

Discussion.—The citrus bud mite problem is very interesting and complex. Available evidence indicates that the mite has undoubtedly been present and widely distributed in the southern portion of this state for many years although its presence was not recognized until 1937. However, there is no evidence to indicate that at any time prior to about 1935 was there any appreciable amount of injury in even an individual planting. The factors influencing the present epidemic condition of this mite are unknown; in fact, there are no indications as yet of a natural decline in its population, nor is there any lessening of its importance as a problem of the lemon industry of this state.

The biological studies are continuing since there are many aspects upon which more information is needed. The control studies are still receiving major consideration in an effort to develop a more effective, less expensive, and otherwise more satisfactory program than exists at present.

SUMMARY.—The citrus bud mite, *Eriophyes sheldoni* Ewing, was first recognized in 1937 when it became evident that this undescribed mite was responsible for causing a characteristic type of injury on lemons near Santa Paula, Ventura County, California.

The adult females are about 170 microns in length by 35 microns in width, while the males are about 120 microns in length by 27 microns in width. There are about 65 to 70 striations on the abdomen. The mites are yellow to orange in color. The eggs are somewhat translucent, almost spherical in shape and average 48 microns in length by 33 microns in width. The larvae, somewhat triangular in shape, are approximately 100 microns in length and have about 52 dorsal and 32 ventral

striations on the abdomen. The nymphs are approximately 130 microns in length and have about 65 dorsal and 46 ventral striations on the abdomen.

The origin of the mite is unknown. It has been found in five counties in the southern portion of California and is also recorded from Queensland and New South Wales in Australia, and from the Island of Oahu, Hawaii. *Citrus* species are the only known hosts. Nursery stock is probably the best medium for disseminating the mite into uninfested areas.

The mites occur in the buds and beneath the buttons of the fruits, where they feed and produce characteristic types of injury. Blasted buds, multiple buds, and deformed twigs, leaves, blossoms and fruits, and bunched growth result from injury to the buds. Blackening of the rind tissue beneath the button of the fruit results from their feeding in this location.

In California the lemon is the only host in fruiting that is seriously affected. Approximately 25,000 acres of lemons are infested although the injury is only important on about 20,000 acres, most of which are in the coastal and intermediate areas. The degree of infestation on Valencia oranges has increased during the past two years. Seed bed budding stock of all varieties, budded nursery trees and young lemon and orange trees set into the orchard are often seriously injured. In Australia, injury has been recorded on bearing citrus trees on most of the common varieties including oranges, lemons, grapefruit and shaddock.

The eggs are deposited singly or in small groups in protected places, although mainly they are found within the buds or on the tender growth of expanding buds and beneath the buttons of fruits. The developmental period, egg to adult, varies with prevailing temperature conditions and was 7 days in the laboratory, while in the field it was 10 days during the summer season and 15 days during the autumn season. The sex ratio of the mites infesting the buds in August was 1 male to 2.3 females, while in December it was 1 male to 20 females. In certain localized areas temperature above 110° F. was apparently responsible for mite mortality as high as 50 per cent. A temperature of 118° F. in Australia apparently caused a complete destruction of mites and eggs.

Owing to the very small size of this mite, the quantitative evaluation of the effectiveness of treatments for control is difficult. A field-sampling method was developed for estimating population levels of the mites in the buds and beneath the buttons of the fruits. Results of treatments are judged principally on the basis of a population census taken just prior to treatment and at appropriate intervals following treatment. Fumigation with HCN and also with vaporized nicotine under tented trees was not satisfactory. The regular petroleum oil that is used on citrus and sulfur or sulfur-containing materials applied as sprays have shown the greatest effectiveness of the various materials tested. Light-medium or medium grade petroleum oil at the usual dosage of 1.67 per cent affords the most generally satisfactory control of the citrus bud mite as well as of the citrus red mite and the black scale. Owing to the adverse effect of a full dosage of oil applied on maturing fruits, light-medium oil at 0.75 per cent in combination with powdered rotenone-bearing roots is commonly used, particularly during the late winter and spring when a large percentage of the crop of lemons is maturing. Ammonium polysulfide, lime-sulfur, wettable sulfur and a so-called "inverted" oil-sulfur mixture are effective in control of the citrus bud mite but have very limited practicability. Of the various aqueous solutions of organic compounds tested, the triethanolamine salt of 2-4-dinitro-6-cyclohexylphenol has shown most promise in preliminary tests.

Predaceous insects and mites commonly found associated with the citrus bud mite do not appear to be of importance in reducing or limiting the population of this Eriophyid.—7-23-41.

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Isolation-Cage Studies of Certain Hemipterous and Homopterous Insects on Sugar Beets Grown for Seed

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Sugar beet seed production in the United States is a comparatively new industry. The first commercial planting of sugar beets for seed in Arizona was made in 1935; today approximately 5,000 acres are grown annually. In certain years the viability of the seed produced has not been satisfactory. This has been true not only in Arizona but in all areas in which the crop has been grown. In the spring of 1938 studies were commenced by the Bureau of Entomology and Plant Quarantine in the Salt River Valley of Arizona to determine what insects were occurring in the beet fields and what effect these insects might be having on the seed produced. Results of the surveys showed that of the insects other than the beet leafhopper, *Eutettix tenellus* (Baker), found in the beet fields in the spring the following were likely to be of greatest economic concern: *Lygus* spp., several species of Pentatomidae, and the false chinch bug, *Nysius ericae* (Schill.). The beet leafhopper was already known to be a pest of beets grown for seed in the Southwest. However, the damage caused by this insect is in the transmission of curly top disease, which tends to reduce the yield rather than the viability of the seed. Under severe curly top conditions the viability is also somewhat affected, but since the curly top symptoms are easily recognized it was suspected that seed viability was being reduced largely by causes other than curly top.

Isolation-cage studies were carried on in the spring of 1938 and 1939 to determine the type of damage attributable to some of the potentially economic insects found to occur in the beet fields. In 1938 the studies were conducted with *Lygus* spp.,[1] *Thyanta brevis* Van D., and *Nysius ericae*. Since time did not permit the work with the last two insects to be started until the seed was too far advanced to give good results, only data regarding *Lygus* spp. are presented. In 1939 the studies included *Lygus* spp.,[1] *Chlorochroa sayi* Stål., *T. custator* (F.), *N. ericae*, and *Myzus persicae* (Sulz.).

DESCRIPTION OF CAGES AND ARRANGEMENT OF EXPERIMENTS.—The cages used for this work were cylindrical and cloth covered, 24 to 30 inches in diameter and 4 to 5 feet tall (Fig. 1), each cage enclosing the entire inflorescence of one sugar beet plant. The frame of the cage consisted of two heavy wire hoops suspended the desired distance apart between two side stakes. A cloth tube of sufficient diameter to go around the hoops and long enough to gather and tie at each end constituted the covering. The bottom end was gathered and tied around the beet seed stalk about 2 feet above the ground; the top was simply gathered and tied. The construction of these cages was such that when not in use they could be folded flat by pushing upward on one side stake and pulling down on the other. This greatly facilitated the transportation of the cages to and from the field. The insects were introduced through the top of the cage, as shown in figure 1.

To lessen the effect of the cage on the plant, it was considered desirable to use a material with as large meshes as possible for cage coverings. Curtain scrim having 16 meshes per linear inch was selected as the ideal material; however, the meshes of this material were too large to retain cer-

[1] A mixture of *Lygus hesperus* Knight and *L. pratensis oblineatus* (Say) as they occurred in the field.

tain of the insects tested, and for these smaller insects a high thread-count cheese cloth was used.

In 1938 the isolation cages involving *Lygus* spp. were set up in pairs, which were replicated 20 times. One cage of the pair contained *Lygus* and the other was kept insect free as a check. Curtain scrim was used as a cage covering and all cages were placed on one variety of beet.

In 1939 the cages were set up as randomized-block experiments, each block being replicated 16 times. Two varieties of beets were used, eight replications on each variety, but since the insects apparently affected both varieties alike no distinction between varieties has been made in this paper. Since two types of cage coverings were used, it was necessary to set the cages up as two experiments, as follows: No. 1, dealing with those insects confined in curtain-scrim cages, and No. 2, dealing with those insects confined in cheesecloth cages. In each experiment a series of insect-free cages were maintained for comparison and are referred to as check cages. Figure 2 shows the 1939 set-up of cages in the field.

SEED ANALYSIS.—At harvest time the seed stalks were cut just below the bottom of the cages. The cages were then folded down and brought to the laboratory with the seed stalks and seed inside. After the stalks had dried the cages were opened and the seed from each threshed, cleaned, and screened by hand. The yield was then determined by weighing and measuring all seed retained by a screen having eight sixty-fourth inch holes. Seed balls passing through a screen having eight sixty-fourth inch holes but retained by a screen having seven sixty-fourth inch holes were considered small seed, and the per cent by weight of this size seed to the total was determined.[1] A 100-cc. sample of the seed retained by the eight sixty-fourth inch screen was next measured out and the seed balls in the sample were counted to

FIG. 1.—Introducing insects into one of the isolation cages. The small cage hanging on the side stake contains the insects being introduced.

[1] The technique of seed analysis was similar for 1938 and 1939, except that in 1938 the per cent of small seed balls was not determined.

FIG. 2.—Aerial view of 1939 isolation-cage set-up. The rectangular screen cages were for other experiments.

obtain a comparative figure on seed-ball size. The sample was then weighed to obtain a figure on weight per unit of volume. The viability of the seed was determined in two ways, by "crack test" and by actual germination. The crack test consisted simply of cracking the seed balls against a hard surface with a hammer, the appearance of starch being taken as an indication of viability; 300 seed balls constituted a sample. The germination tests were made by a recognized seed laboratory, 400 balls constituting a sample.

Experiment 1, 1939.—As previously stated, this experiment dealt with those insects confined in the curtain-scrim cages. Each block consisted of four cages, one cage a check and one for each of the following insects: *Lygus* spp., *Chlorochroa sayi*, and *Thyanta custator*. Original numbers introduced were *Lygus* 25, *T. custator* 20, and *C. sayi* 10. These numbers were maintained as nearly as possible by replacing dead insects with live ones until after reproduction had been noted to occur within the cages. The numbers used for original introductions were based on the size of the insect and on the comparative numbers found to occur in the beet fields.

All insects were introduced in April on plants in the blossom stage and allowed to remain until harvest time in June. Observations were made from time to time to determine whether the insects had any visible effect on the plants. No damage or alterations in type of growth could be seen, but after the seed had been harvested and analyzed definite differences in the quality of the seed became apparent (Table 1).

There were no appreciable differences among the various cages in the total weight or volume of the seed produced, in the per cent of small seed balls, or in the size of the seed balls. There was, however, a marked reduction in the germination of the seed produced on plants fed upon by each of the three species. *Chlorochroa sayi* reduced the germination from 89.3 per cent to 13.4 per cent, or more than did either *Lygus* or *Thyanta custator*. According to the crack-test method there was no appreciable difference in viability among the three species, although there was a reduction in the per cent of viable seed produced in the insect cages over that produced in the check cages. Each species reduced the weight of seed per 100 cubic centimeters, but this effect was small and was about the same for the three species.

At the end of the experiment all insects were recovered from the cages to determine the degree of reproduction. There was a definite difference in reproductive ability among the three species. From the *Lygus* cages there was a mean recovery of 96.1 adults and 2.4 nymphs, or a total of 98.5 insects per cage; from the *Chlorochroa sayi* cages a mean recovery of 39.2 adults and 27.1 nymphs, or a total of 66.3 insects per cage; and from the *T. custator* cages a mean recovery of 41.3 adults and

Table 1.—Yield and quality of sugar beet seed produced in isolation cages containing different species of plant bugs, Phoenix, Ariz., 1939.

Treatment	Weight, Grams	Volume Cc.	Per Cent of Small Balls by Weight	Number of Balls per 100 Cc.	Weight per 100 Cc. Grams	Per Cent Viable	
						Crack test	Germination test
			Experiment 1				
Lygus spp.	57.5	320.6	13.6	974.8	18.1	33.9	32.2
Chlorochroa sayi	70.6	374.8	9.5	1,052.5	17.7	35.4	13.4
Thyanta custator	70.3	409.4	11.1	1,113.6	17.9	41.3	32.5
Check	85.9	445.2	12.3	1,007.5	19.7	92.2	89.3
Difference required for significance	—[1]	—[1]	—[1]	—[1]	1.2	13.4	14.1
			Experiment 2				
Myzus persicae	13.5	67.3	44.4	—[2]	—[2]	63.7[3]	—[2]
Nysius ericae	65.6	335.9	9.5	984.4	20.2	83.2	75.2
Check	66.1	338.3	8.3	977.7	20.6	82.6	78.8

[1] None of the differences between treatment-means significant according to the *F* test.
[2] Insufficient quantity of seed for this test.
[3] Differences in per cent viability not significant according to the *F* test.

1.8 nymphs, or a total of 43 insects per cage.

Experiment 2, 1939.—This experiment dealt with those insects confined in the cheesecloth cages. Each block consisted of three cages, one cage containing *Myzus persicae*, one containing *Nysius ericae*, and one used as a check. Introductions were made in April during the blooming period of the plants. No definite number of *M. persicae* was introduced. Infested beet leaves were placed in the cages and the aphids were allowed to increase until such a heavy infestation was produced that the life of the plant was endangered. At this point ladybird beetles were introduced and the infestation was cleaned up. A total of 500 adults of *N. ericae* were introduced. Very little reproduction of these insects occurred, and as populations decreased the numbers remaining within the cages were estimated and further introductions made to bring the populations up to approximately 500. At harvest time the mean number of *N. ericae* recovered was 465 per cage.

As in experiment 1, observations were made from time to time to determine whether the insects had any visible effect on the plants. *Myzus persicae* became exceedingly numerous, causing the leaves to wilt and turn yellow. The terminal tips of the spikelets wilted and drooped and the whole plant became a sticky mass of honeydew. However, after the infestation had been cleaned up by the ladybird beetles the plants recovered. New growth appeared and some of the plants bloomed again and set seed, but this seed was still green at harvest time and usually did not participate in the yield. *Nysius ericae* had no visible effect on the plants.

When the seed was mature it was harvested and analyzed as previously described. The results of the analysis are presented in table 1.

There was a definite reduction in both weight and volume of seed produced in the *Myzus persicae* cages as compared with that produced in the check cages. The per cent of small balls produced was considerably larger in the aphid cages than in the check cages, but the per cent of viable seed produced as determined by the crack test was not significantly reduced. Since in most cases less than 100 cc. of seed was produced per cage, the number and weight of seed per 100 cc. could not be determined. Also the quantity of seed available made it impossible to determine viability by both crack test and germination; therefore no data are available for germination.

From a comparison of the data from the *Nysius ericae* cages with those from the check cages, it can be seen that the results are similar, which would indicate that these insects up to 500 per plant have no measurable effect on either the quantity or quality of seed produced.

The viable seed produced within the check cages of experiment 1 is about 10 per cent lower than that produced in the check cages of experiment 2. These results would indicate that the curtain-scrim cages had less effect on the plants and therefore would be more desirable to use wherever possible.

Experiments in 1938.—*Lygus* was introduced into the cages when the beets were in the late blossom stage, or slightly later in the development of the plant than in 1939. Fifty *Lygus* adults were introduced into each cage, but no further introductions were made. Observations indicated that the insects were having no visible effect on the plants, but seed analysis after harvest showed practically the same differences in seed quality as in 1939. Data from this analysis are presented in table 2.

Table 2.—Yield and quality of sugar beet seed produced in isolation cages containing *Lygus* spp., Phoenix, Ariz., 1938.

Treatment	Weight, Grams	Volume, Cc.	Number of Balls per 100 Cc.	Weight per 100 Cc., Grams	Per Cent Viable	
					Crack Test	Germination Test
Lygus spp.	74.1	454	749	16.3	23.0	26.7
Check	80.7	446	879	18.1	71.7	75.2

The quantity of seed, by either weight or volume, was not reduced by *Lygus*, nor was the size of the seed balls decreased. There may have been some reduction in the weight of seed per 100 cc., although this difference is not marked. There was, however, a marked decrease in the per cent of viable seed produced in the *Lygus* cages as compared with the check cages. This decrease in viability was shown by both the crack test and germination. This mean germination for seed produced in the check cages was 75.2 per cent as compared with a mean germination of 26.7 per cent for the seed produced in the *Lygus* cages.

Considerable difficulty was experienced in 1938 in keeping *Lygus* out of the check cages. Nymphs of *Lygus* appeared in appreciable numbers in some of the check cages, apparently from eggs deposited in the seed stalks before the cages were set up. These nymphs were removed when they were discovered but apparently did some damage. For this reason the per cent of viable seed produced in the check cages was lower in 1938 than in 1939, as can be seen in tables 1 and 2.

SUMMARY.—Surveys of fields of sugar beets grown for seed in the Southwest indicated that certain insects likely to be of economic concern occur in the fields. In 1938 and 1939 isolation-cage studies were conducted to determine the type and extent of damage attributable to each of these insects. Cages designed to enclose the entire inflorescence of a single sugar beet plant were placed in the field. Insects were introduced into certain of the cages and others were kept free of insects. The seed was harvested and analyzed to determine the quantity and quality produced in each cage. The damage attributable to the various insects was ascertained by a comparison of the seed produced in the insect-infested cages with that produced in the cages from which insects had been excluded.

Results of cage studies showed that *Lygus* spp., *Chlorochroa sayi* Stål., and *Thyanta custator* (F.) are capable of materially reducing the per cent of viable sugar beet seed produced per plant. The number of seed balls was not reduced by these insects, but the seed was slightly lighter in weight, as was indicated by a reduction in weight per unit of volume. *Nysius ericae* up to 500 per plant had no measurable effect on the quantity or quality of seed produced. Heavy infestations of *Myzus persicae* in cages drastically reduced the quantity of seed produced but did not significantly reduce the viability. —7-23-41.

Laboratory Control Studies on the Greenhouse Thrips[1]

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The greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), is an important pest of Valencia oranges in certain localized areas of California. It first came into prominence as a serious pest of Valencia oranges at Rancho Santa Fe, San Diego County, California, in 1936. Since that time it has become an increasingly more important pest in this locality. Limited infestations have been reported from other coastal areas of California, but as yet the problem has not reached serious proportions in these districts.

Fruit scarring caused by this insect feeding on the surface constitutes the major problem on citrus. Fruits exhibiting a considerable degree of scarring are rendered unmarketable and those less severely scarred are usually reduced in grade of quality. While some feeding occurs on the leaves, particularly on the lower surface, the damage caused to foliage is not considered to be of economic importance.

Observations on the biology and control of this insect have been frequently recorded in connection with its occurrence in greenhouses throughout the world since its description by Bouché in 1883. Russell (1909) reported on the habits and life history of this species and suggested a number of control measures for use in greenhouses. These included fumigation with hydrocyanic acid gas or nicotine and spraying with mixtures containing nicotine sulfate, kerosene or water only. Rivnay (1935) described the biology of this species in Palestine and mentioned its occurrence on citrus in that country. Boyce & Mabry (1937) conducted detailed studies on the control of the greenhouse thrips on oranges in California. They showed that pyrethrum, nicotine sulfate, β-butoxy-β′-thiocyanodiethylether (*Lethane*) and 2, 4-dinitro-6-cyclohexylphenol in sprays and dusts were effective against this species, and that rotenone materials used in dusts and sprays were not very promising.

Because of the increasing importance of this pest in the field, a laboratory study

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was undertaken in 1939 to evaluate further the effectiveness of various contact insecticides, stomach poisons, and ovicides for the control of this insect.

SPRAYS AND DUSTS ON THE ADULT THRIPS.—Several spray and dust mixtures were tested on the adults of this species. The selection of materials and concentrations used were influenced to a great extent by the need for practical mixtures that can be used in the field. Therefore only materials that can be applied on citrus with some degree of safety were used, and at concentrations that are likely to be practical and noninjurious to fruit and foliage.

The procedure for testing spray materials consisted of applying spray to the insects on the orange, placing the fruit in a constant environment, and counting the dead and live insects after seven days. Fifty adult thrips were placed on a mature Valencia orange, which was sprayed with the laboratory spray rig, using a "fog spray," so that none of the insects were dislodged. This equipment was designed to simulate as nearly as possible field spraying conditions. It was equipped with a 12-gallon spray tank having a power-driven agitator and a reciprocating pump that delivered 3 gallons per minute at a pressure of 300 pounds per square inch. Each fruit was sprayed individually and was rotated by a mechanical stage through one complete revolution while being sprayed. After receiving this treatment, the fruit was placed immediately in a separate cage which was kept in a constant temperature cabinet operating at 70° F. and with a relative humidity of 50 per cent. The cage consisted of a cardboard cylinder 5 inches high and 4 inches in diameter, covered at each end with unbleached muslin. The fruit rested on a small pedestal which eliminated contact between the fruit and the container. An air current was forced through the cage to eliminate accumulated vapors that might act as fumigants.

Table 1.—Net mortality obtained with various sprays on adult greenhouse thrips.

MATERIALS AND AMOUNT PER 100 GALLONS	NUMBER OF INSECTS	NET MORTALITY[1] (Per cent)
Pyrethrum extract (2.57% pyrethrins) 0.5 pint	379	100.0
Petroleum oil[2] 0.5 gal. plus pyrethrum extract (2.57% pyrethrins) 0.25 pint	344	100.0
Petroleum oil 0.5 gal. plus powdered pyrethrum flowers (0.8% pyrethrins)2 lbs.	305	99.6
Petroleum oil 0.5 gal. plus nicotine sulfate solution (40% nicotine) 0.5 pint	201	99.3
Petroleum oil 0.5 gal. plus nicotine sulfate solution (40% nicotine) 0.67 pint	235	100.0
Nicotine-bentonite mixture (3.75% nicotine) equal to 1 pint nicotine sulfate solution (40% nicotine)	469	78.7
Petroleum oil 0.5 gal. plus 2(4-tert.-butylphenoxy) ethanol[3] solution of derris extract (solution contains 4% rotenone) 0.5 pint	388	99.6
DN[4] 4 oz. (as nicotine salt) plus *Vatsol OT*[5] 4 oz.	368	100.0
DN 4 oz. (as triethanolamine salt) plus *Vatsol OT* 4 oz.	227	93.7
Petroleum oil 0.5 gal. plus DN (as dicyclohexylamine salt) 4 oz. plus blood albumin spreader 0.25 oz.	278	100.0
Petroleum oil 0.5 gal. plus *Lethane 440*[6] 0.5 pint	77	93.2
Petroleum oil 0.5 gal.	365	40.2

[1] Computed by Abbott's (1925) formula.
[2] Highly refined light-medium containing 1 per cent glyceryl monooleate.
[3] Solubilizer for the derris extract and oil.
[4] 2, 4-dinitro-6-cyclohexylphenol.
[5] A proprietary wetting agent consisting of a dioctyl ester of sodium sulfosuccinate.
[6] A proprietary material containing 18.75 per cent β-butoxy-β'-thiocyano diethylether.

Table 2.—Net mortality obtained with certain dust mixtures on adult greenhouse thrips.

DUST MIXTURE	NUMBER OF INSECTS	NET MORTALITY[1] (Per cent)
DN[2]—*Frianite*[3] (1 per cent DN)	376	100.0
DN as dicyclohexylamine salt—*Frianite* (1 per cent DN)	538	99.7
Powdered pyrethrum flowers (0.2 per cent pyrethrins)—*Frianite*	505	99.5
Powdered derris root (1.0 per cent rotenone)—*Frianite*	483	76.1
Frianite	425	45.3

[1] Computed by Abbott's (1925) formula.
[2] 2,4-dinitro-6-cyclohexylphenol.
[3] A proprietary pumiceous earth diluent.

The technique for testing dust materials was practically identical with that for testing sprays. Each orange was dusted with 2 grams of the dust mixture, which was applied with a modified De Vilbis powder blower while the orange was rotated on a mechanical stage.

From an examination of the data in tables 1 and 2, it is apparent that the adult stage of this insect is readily killed by a number of sprays and dusts. All of the pyrethrum mixtures were extremely effective and the nicotine sulfate sprays were also effective, although the stabilized nicotine-bentonite mixture was somewhat inferior. The 2, 4-dinitro-6-cyclohexylphenol in the form of dusts and sprays was also very toxic to this species. It is of interest that the *Frianite* dust and the spray containing 0.5 per cent petroleum oil without added toxicants afforded an appreciable mortality.

STOMACH POISONS ON THE ADULT STAGE.—In view of the fact that several

other species of thrips are successfully controlled by materials that presumably act as stomach poisons, several of these materials were tested on the greenhouse thrips. Potassium antimony tartrate[4] (tartar emetic) and certain related antimony compounds, as well as two fluorine stomach poisons were tested.

Table 3.—Effectiveness of various stomach poison residues[1] in killing adult greenhouse thrips.

Stomach Poison in Residue	Number of Insects	Net Mortality[2] (Per cent)
Potassium antimony tartrate	397	70.5
Calcium antimony tartrate	305	55.0
Zinc antimony tartrate	346	42.5
Potassium antimony citrate	314	38.3
Sodium fluoaluminate (natural cryolite)	403	9.5
Barium fluosilicate	451	3.7

[1] Each residue was deposited by a spray containing 4 pounds of the stomach poison plus 4 pounds of sucrose per 100 gallons.
[2] Computed by Abbott's (1925) formula.

The technique for evaluating stomach poison residues consisted of spraying a mature Valencia orange and placing 25 adult thrips on the sprayed surface when dry. A count of dead and live thrips was made at the end of seven days. Residues were deposited by placing the orange at the bottom of a vertical cylinder, where it was exposed to a fine mist of the spray for a definite interval of time. A spray nozzle fastened at the top and center of the cylinder served to direct the spray downward over the orange. The distance from the nozzle to the orange was about 4 feet, and the cylinder was approximately 30 inches in diameter. The cylinder served as a shield to prevent air currents from disturbing the spray pattern. This spraying technique resulted in a uniform and reproducible deposit of very fine droplets, distributed uniformly over the upper surface of the fruit. Each material was used at a concentration of 4 pounds per 100 gallons, with an equal quantity of sucrose (white cane sugar). After the fruit had dried, a small cylindrical cage fastened over the upper surface served to confine the thrips to a limited area. The cage consisted of a metal cylinder 1.25 inches in diameter by 0.25 inch high, with one end covered with muslin. It was fastened to the fruit with paraffin.

[4] The chemical name for tartar emetic is written in at least five different ways in standard chemical and pharmaceutical references. The authors are using the terminology given in the 24th edition of the Handbook of Chemistry and Physics, Chemical Rubber Publishing Company (1940–1941).

The insects apparently fed normally under these conditions and after seven days, when counts were made, the entire surface of the fruit where the insects were confined was severely scarred. A constant temperature of 70° F. with a relative humidity of 50 per cent was maintained during the seven-day period.

Results of the tests with stomach poisons are presented in table 3.

As a group, the antimony compounds were much more toxic to the greenhouse thrips than were the fluorine compounds. Tartar emetic was the most effective material tested, but the toxicity of this compound was not of sufficient magnitude to offer much promise in field control. It has been demonstrated since, in field tests, that tartar emetic is not effective for control of the greenhouse thrips.

Spray Materials Against the Egg Stage.—An important problem in the control of greenhouse thrips on citrus is the reinfestation from eggs that hatch after sprays and dusts have been applied. In a field life history study conducted at Rancho Santa Fe, San Diego County, California, during a period from November, 1939, to May, 1940, it was shown that the range of the incubation period for individual eggs was 27 to 101 days. A considerable degree of overlapping of generations was also observed. From a consideration of these factors a large proportion of the work on this project was devoted to evaluating the ovicidal effectiveness of various spray mixtures.

The "kidney-shaped" eggs of the green house thrips are deposited singly in the rind of the fruit or in the tissue on the lower surface of the mature leaves. While eggs are occasionally deposited freely on the surface or partially inserted in the tissue, most of them are completely embedded in the tissues of the fruit and leaves. The location of the egg affords a degree of protection and probably accounts for the failure of many sprays and dusts to give control in the field.

A technique was developed for testing ovicides which afforded an accurate evaluation of materials and simulated as nearly as possible actual field spraying conditions. This method consisted of spraying eggs of a definite age deposited in a limited area of the orange surface. The percentage of eggs that hatched following treatment was used as a criterion for

evaluating the effectiveness of the spray. For obtaining eggs in a limited area of the fruit, 100 adults were placed in a cylindrical cage on each mature Valencia orange. The method of confining adults on the fruit surface was identical to that described in the previous section. Confinement of the thrips in this manner for a period of two days resulted in the deposition of from 100 to 400 eggs. After ten days, or approximately one half of the embryonic developmental period had elapsed, the fruits were sprayed with the mixtures being tested, using the laboratory sprayer. The fruits were rotated on the revolving stage and the area where the eggs were deposited was permitted to pass but a single time through the spray stream. A few days after treatment and before hatching occurred, another cage, similar in design but slightly larger than the one used for confining thrips to the surface, was placed over the area on the fruit where the eggs were deposited. After hatching the larvae were removed and counted. When all the viable eggs had hatched the excrement was washed from the fruit with water, the egg-deposited area was painted with an acetone solution of Sudan III, and the number of eggs that had been deposited was determined. The application of Sudan III in acetone resulted in a dark red coloration of the ruptured tissues where the egg had been inserted. This technique greatly increased the speed and accuracy of counting.

The first group of materials tested included several spray oils. Highly refined light-medium grade petroleum spray oil[5] was tested at concentrations of 0.5 per cent and 1.67 per cent. This grade of oil and also a medium grade is used at the 1.67 per cent concentration as a regular practice for the control of scale insects and mites in the district where the greenhouse thrips is a serious problem. It was important, therefore, to determine the effect of this treatment on the greenhouse thrips egg population. The 0.5 per cent concentration represents the dosage of this grade of oil that is recommended for use with nicotine sulfate or pyrethrum extract as a specific control measure for the greenhouse thrips. Kerosene, diesel oil, and peanut oil were chosen as representatives of other types of oils and are used at maximum concentrations that could probably be used safely on citrus.

Table 4.—Effect of various oil sprays on the mortality of 10-day-old eggs of greenhouse thrips.

Oil and Amount per 100 Gallons	Number of Eggs	Net Mortality[1] (Per cent)
Petroleum (highly refined light-medium)[2] 0.5 gallon	2854	17.6
Petroleum (highly refined light-medium) 1.67 gallons	2028	40.6
Kerosene 8 gallons[3]	1094	1.4
Diesel 0.5 gallon[3]	2182	10.6
Peanut 0.5 gallon[3]	2335	24.3

[1] Computed by Abbott's (1925) formula.
[2] Contains 1.0 per cent glyceryl monooleate.
[3] Used with 4 ounces blood albumin spreader.

Table 5.—Comparative effectiveness of pyrethrum extract[1] and nicotine sulfate[2] in 0.5 per cent petroleum oil[3] sprays on 5 and 10-day-old eggs of greenhouse thrips.

Materials and Amount per 100 Gallons	Eggs 5 Days Old		Eggs 10 Days Old	
	Number of eggs	Net mortality[4] (Per cent)	Number of eggs	Net mortality[4] (Per cent)
Pyrethrum extract				
0.5 pint	1570	100.0	1332	99.2
0.25 pint	1582	99.9	1149	96.9
0.125 pint	1595	71.9	1269	75.1
0.062 pint	1433	73.4	1367	49.9
Nicotine sulfate				
2 pints	1728	84.2	1392	97.9
1 pint	1532	79.6	1345	91.2
0.5 pint	1477	7.9	1070	69.3
0.25 pint	1764	17.7	1187	24.5

[1] A proprietary pyrethrum extract containing 2.57 per cent pyrethrins.
[2] A proprietary nicotine sulfate solution containing 40 per cent nicotine.
[3] Highly refined light-medium containing 1 per cent glyceryl monooleate.
[4] Calculated from Abbott's (1925) formula.

Results are presented in table 4.

Extensive tests were conducted to compare the effectiveness of nicotine sulfate[6] (40 per cent nicotine) and pyrethrum extract[7] (2.57 per cent pyrethrins) in a spray containing 0.5 per cent of a highly refined light-medium petroleum oil.[5] These two materials have been used extensively for control of the greenhouse thrips on citrus in California. Boyce & Mabry (1937) recommended the use of either material at a dosage of 0.67 pint per 100 gallons with 0.5 per cent of a highly refined light-medium petroleum spray oil.[5] They observed that high initial kills of all postembryonic forms were obtained with both materials and that appreciable numbers of eggs were also killed by these treatments.

Eggs 5 and 10 days old were used in this phase of the project in order to determine

[5] University of California rating No. 3. For specifications see California Agr. Exp. Sta. Bul. 527, 1932.
[6] *Black Leaf 40*
[7] *Pyrocide 20.*

Table 6.—Net mortality obtained with various materials used with petroleum oil[1] sprays on 10-day-old eggs of greenhouse thrips.

Oil (Gallons)	Materials and Dilution[2] — Materials used with the oil	Number of Eggs	Net Mortality[3] (Per cent)
0.5	DN[4] 4 oz. (as dicyclohexylamine salt) plus blood albumin spreader 0.25 oz.	2,449	100.0
0.5	DN 0.5 per cent by weight of the oil	596	94.1
0.5	DN (as nicotine salt) 0.25% by weight of the oil	328	68.8
0.5[5]	Powdered pyrethrum flowers (0.8% pyrethrins) 4 lbs.	1,927	97.0
0.5	Sulfur (325 mesh) 4 lbs. plus blood albumin spreader 4 oz.	595	93.2
0.5	Naphthalene 5% by weight of the oil	540	86.6
0.5	N, N-amylbenzylcyclohexylamine 1 pint	1,224	79.3
0.5	Oleic acid 1 pint	1,206	79.1
1.67	2(4-tert.-butylphenoxy)ethanol[6] solution of derris extract (solution contains 4% rotenone) 0.5 pint	1,412	79.1
1.67	*Cardolite*[7] solution of derris extract (solution contains 4% rotenone) 0.5 pint	1,650	78.5
0.5	Dibutylphthalate[6] solution of derris extract (solution contains 2% rotenone) 1 pint	1,481	34.0
0.5	2(4-tert.-butylphenoxy)ethanol[6] solution of derris extract (solution contains 4% rotenone) 0.5 pint	1,470	6.5
0.5	Pinyldiphenylether 1 pint	647	76.1
0.5	Diisobutylketone 1 pint	2,155	60.9
0.5	Turpentine 1 pint	1,576	58.8
0.5	*Lethane 410*[8] 0.67 pint	516	51.9
0.5	Carbon bisulfide 1 pint	507	30.1
0.5	2,Chlor 2′ (2,4,6-trichlorphenoxy)diethylether 1 pint	1,890	27.3
0.5	Dichlorethylether 1 pint	2,290	20.9
0.5	*NNO*[9] 1 pint	462	15.3
0.5	Powdered tobacco (1% nicotine) 10 lbs.	772	15.3
0.5	3,5-dinitro-o-cresol 1% by weight of the oil	2,487	0.0
0.5	*o*-Dichlorbenzene 1 pint	2,259	0.0

[1] Highly refined light-medium containing 1 per cent glyceryl monooleate.
[2] Expressed as amount per 100 gallons except in mixtures containing solid toxicants dissolved in oil, in which case dilution is expressed as per cent by weight of the oil.
[3] Calculated from Abbott's (1925) formula.
[4] 2,4-dinitro-6-cyclohexylphenol.
[5] Highly refined light-medium tank mix, plus 4 ounces blood albumin spreader.
[6] Solubilizers for derris extract and oil.
[7] A proprietary oil-derris extract solubilizer consisting of the condensation polymer of cardanol and formaldehyde.
[8] A proprietary material containing 75 per cent β-butoxy, β′-thiocyanodiethylether.
[9] A proprietary material consisting of anhydrohexitol cocoanut fatty acid esters.

the relative susceptibility of eggs in both stages of development to these materials. Data obtained are presented in table 5.

A group of miscellaneous materials were tested in a preliminary manner in order to find materials, other than nicotine and pyrethrum, that show enough promise to warrant further more detailed study.

Table 7.—Effect of various aqueous sprays on the mortality of 10-day-old eggs of greenhouse thrips.

Materials and Amount per 100 Gallons	Number of Eggs	Net Mortality[1] (Per cent)
Ammonium polysulfide solution[2] 2 gals. plus sodium caseinate spreader 3 oz.	2,372	28.3
Lime-sulfur[3] solution 2 gals. plus sodium caseinate spreader 3 oz.	2,287	21.6
Powdered tobacco (1% nicotine) 10 lbs.	772	15.3
Sulfur (325 mesh) 4 lbs. plus blood albumin spreader 4 oz.	762	0.0

[1] Calculated from Abbott's (1925) formula.
[2] Solution contains 31.6 per cent sulfur.
[3] Commercial 32° Baumé.

Most of the materials were used with 0.5 per cent highly refined light-medium spray oil,[5] although some were used with the same kind of oil at 1.67 per cent, and others were used without oil.

Materials that had not been applied on citrus previously were used at a concentration of 1 pint per 100 gallons, with 0.5 per cent of the oil. Materials that had been applied to citrus previously were used at concentrations that had been fairly safe and practical for field usage.

Results of these tests are summarized in tables 6 and 7. Table 6 contains data on materials used in sprays with petroleum oil, and table 7 contains data on materials used without oil.

DISCUSSION OF RESULTS ON TESTS WITH SPRAYS AGAINST THE EGG STAGE.—Data in table 4 indicate that about 40 per cent of the eggs are killed by a spray containing 1.67 per cent of a highly refined

light-medium petroleum oil. This is not a sufficiently high mortality for field control but it indicates that oil sprays used for control of other pests has an appreciable effect in reducing the egg population of the greenhouse thrips. The spray containing 0.5 per cent petroleum oil also caused some mortality. It is of interest that kerosene at 8 per cent had very little effect upon the eggs. Results obtained with Diesel oil and peanut oil were probably not significantly different from the results with petroleum oil when used at the same concentration.

Data presented in table 5 on the comparative effectiveness of pyrethrum extract and nicotine sulfate solution in sprays containing 0.5 per cent petroleum oil show that both materials are very toxic to eggs of the greenhouse thrips. It is also apparent that the pyrethrum extract was much more effective than the nicotine sulfate solution. This is evidenced by the fact that about the same degree of control was obtained with 0.25 pint of the pyrethrum extract per 100 gallons as was obtained with 2 pints of the nicotine sulfate solution. This indicates that the pyrethrum extract is about eight times as toxic to eggs of this species as is the nicotine sulfate solution. There was some indication that both materials were more effective against eggs in the advanced stage of development. This is less evident in the case of the pyrethrum extract than in the case of the nicotine sulfate solution.

Data presented in tables 6 and 7 indicate that several materials other than pyrethrum and nicotine offer promise as ovicides for greenhouse thrips. The most promising of these was the dicyclohexylamine salt of 2, 4-dinitro-6-cyclohexylphenol. The parent phenol dissolved in the oil was also very effective, but the nicotine salt of this compound was less effective than certain other materials. As a group, the sprays containing rotenone were relatively ineffective. This is in agreement with the findings of other workers and indicates that the eggs of this species are very tolerant to rotenone. The spray mixture of sulfur and oil was also effective in killing eggs of the greenhouse thrips but sulfur in sprays without oil was relatively ineffective. This indicates that the sulfur was effective in these laboratory studies by virtue of the fact that it was carried to the eggs in the oil phase. The residual sulfur on the fruit had little apparent effect on the larvae when they emerged from the eggs.

SUMMARY.—Laboratory control studies were conducted on the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), using the Valencia orange as a host. A number of materials were tested as sprays and dusts against the adult stage at concentrations that are likely to be practicable for field usage on citrus. The adults of this insect were readily killed by a number of materials in sprays and dusts. Pyrethrum was extremely toxic and sprays containing nicotine sulfate and dusts of 2, 4-dinitro-6-cyclohexylphenol were also very effective.

Certain antimony and fluorine stomach poisons used with sucrose were tested on the adult stage and none were found to be effective enough to offer much promise. The antimony compounds were more effective than the fluorine materials, and tartar emetic was the most promising of the antimony compounds.

Various materials were tested against eggs of the greenhouse thrips. A comparison of the effectiveness of certain spray oils shows that an appreciable mortality of eggs occurred when highly refined light-medium petroleum oil was used at 1.67 per cent. Kerosene used at 8 per cent had little effect. The effectiveness of spray mixtures of highly refined light-medium petroleum oil with nicotine sulfate solution and pyrethrum extract were compared. The results of these tests indicate that pyrethrum extract with petroleum oil was approximately eight times as effective as nicotine sulfate and petroleum oil. Numerous other materials were tested in sprays, with and without oil, against eggs of this species. The most effective materials, other than pyrethrum extract, were 2,4-dinitro-6-cyclohexylphenol and the dicyclohexylamine salt of this compound. A spray mixture containing 0.5 per cent of a highly refined light-medium petroleum oil and sulfur was also effective but sulphur alone was not.[1]—7-23-41.

[1] The authors are grateful to A. M. Boyce for suggesting and outlining the problem and for valuable advice and criticisms on the conduct of the work. The suggestions and help of J. F. Kagy and G. L. McCall on certain phases of the project are greatly appreciated.

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Methyl Bromide Fumigation of Strawberry Planting Stock to Control *Paria canella* var. *quadrinotata* (Say)

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The strawberry rootworm, *Paria canella* var. *quadrinotata* (Say), is one of the major pests of strawberries in the central coast and Sacramento districts in California. In recent years the insects became established in the Wheatland area where the University of California has been carrying on an extensive breeding program for the development of new strawberry varieties. In order to minimize the danger of transferring the *Paria* with the planting stock to new and uninfested commercial fields, we were requested to conduct experiments on some feasible method of destroying the adult stage.

The success of methyl bromide in recent years for the treatment of quarantined plant products for the control of various insects prompted the use of this fumigant. Preliminary tests with methyl bromide in the winter of 1939 showed that it was highly toxic to adult beetles. In the early spring of 1940, further tests were undertaken at Sacramento[1] in an effort to determine plant tolerance to methyl bromide and the minimum concentration of the fumigant necessary to obtain a 100 per cent kill of the adults.

VACUUM FUMIGATION.—Dormant commercial Banner and Nich Ohmer planting stock were used in all tests conducted during the spring of 1940. The plants were received from Shasta County on March 25, 1940; and the following day, they were taken to Sacramento to be fumigated. Fumigation tests were made by using 2 and 3 pounds of methyl bromide per 1000 cu. ft. at time exposures of 1, 2, and 3 hours. The foliage and the roots of the plants were exposed directly to the methyl bromide gas in all cases except two lots where the plants were packed in crates with moist sphagnum moss to simulate commercial conditions.

The insects were collected in the field a day prior to fumigation and were caged in fine-mesh brass screen tubes, 4 inches long and 1 inch in diameter, which were placed with the plants to be fumigated at various dosages and time exposures. Fifty beetles were used for each test.

The capacity of the fumigation chamber was 137 cu. ft. In all of the tests of vacuum fumigation, the chamber was exhausted to a 27-inch vacuum, and the proper dosage of methyl bromide, after being measured in the applicator, was injected simultaneously with the first one-third of the air as the vacuum was released slowly. The plants were exposed to the gas at atmospheric pressure for the remainder of time. To prevent stratification of the gases in the chamber, a fan was automatically operated at regular intervals. The temperature was kept at 72 to 74° F. by means of steam heated pipes.

At the close of the treatment, plants which were packed in crates with sphagnum moss treated with 2 or 3 pounds of methyl bromide per 1000 cu. ft. for a 3-hour period were washed with air by subjecting them to a 27-inch vacuum before removal, while the remaining lots were taken out without the application of a second vacuum. It was thought at the time that a second vacuum would remove any residual gas which would contribute to plant injury at higher concentrations and longer time exposures.

After treatment the plants were labeled and repacked in moist sphagnum moss. Due to heavy rains which made it impossible to prepare planting beds, the plants

[1] The author wishes to acknowledge his indebtedness to D. B. Mackie and W. B. Carter of the California State Dept. of Agric. for helpful aid and suggestions, and to L. M. Smith, Univ. of California, under whose supervision this work was conducted.

were placed in cold storage (34° F.) and held for two weeks, after which time the lots were set out at random in three rows. The plants were given the same cultural care as practiced in the central coast district of California.

ATMOSPHERIC FUMIGATION.—In December 1939, tests with atmospheric fumigation were conducted with potted, non-dormant plants, grown in the greenhouse. *Fragaria chiloensis* and Banner, Dorsett, and Klondike strawberry plants were used. The plants were treated at concentrations of 1, 2, 3, 4, and 5 pounds of methyl bromide per 1000 cu. ft. for a 2-hour exposure with temperatures ranging from 79 to 86° F. The fumatorium was 7.5 cu. ft. in capacity. A fan was run automatically at regular intervals within the fumigator to prevent stratification of the gases. Fifty beetles were caged in brass screen tubes for each test.

TOXICITY TO ADULT *Paria*.—After the treatment, the beetles were removed from the cages, placed in cloth covered battery jars, and provided with water and fresh strawberry leaves. Observations made immediately after the treatment showed that there were no differences in the activities of the treated and untreated beetles. At the expiration of 24 hours, however, the toxic action of the methyl bromide became apparent. Complete kills were obtained at 2 pounds per 1000 cu. ft. for a 3-hour period or at 3 pounds for 2 hours. In the 2-pound 1-hour exposure, the beetles remained active for the duration of the counts but all died within two weeks. In the case where 48 per cent and 96 per cent of the beetles were killed, those beetles which survived, were very inactive and walked with difficulty. The results are presented in table 1.

With atmospheric fumigation, preliminary tests made in the winter of 1939 showed that a 100 per cent kill can be obtained by using 2 pounds of methyl bromide per 1000 cu. ft. for a 2-hour period at 79 to 81° F. One pound per 1000 cu. ft. for a 2-hour period at 86 to 88° F. gave only a 22.5 per cent kill.

EFFECT OF METHYL BROMIDE ON PLANTS.—Various workers have reported on the effect of methyl bromide fumigation on strawberry plants. Haller (1938) reported that fumigation of the plants with methyl bromide, at the time of storage in December, with 3 pounds per 1000 cu. ft., for 4 hours at 60° F. resulted in a 53 per cent stand compared with a 76 per cent stand for a comparably stored lot that was not fumigated. Two lots of Howard 17 (Premier) plants fumigated just before they were set out in April exhibited no injury. Smith[2] obtained data on the fumigation of dormant planting stock for the destruction of *Tarsonemus pallidus* Banks and found that methyl bromide was toxic to the plants when the product of the pounds of methyl bromide and the time in hours exceeded the number seven, at a temperature of 65° F. Ritcher (1940) reported that of the varieties tested no injury to dormant plants resulted from a 2-hour exposure to 3 pounds of methyl bromide per 1000 cu. ft. at temperatures below 80° F. In one lot fumigated at atmospheric pressure at 87–92° F., using 3 pounds per 1000 cu. ft. for a 2-hour period, a stimulation of growth of Blakemore was noted, whereas Premier plants subjected to the same condition were injured by the treatment. Non-dormant plants were severely injured by 3 and 4 hours exposure to 3 pounds of methyl bromide per 1000 cu. ft.

Table 1.—The effect of methyl bromide vacuum fumigation on *Paria canella* adults. Temperature 72–74° F.

Lb. / 1000 Cubic Ft.	Exposure, in Hours	Per Cent Dead, after 24 Hours	48 Hours	120 Hours	Per Cent Kill after 120 Hours
2	1	0	0	0	0
2	2	96	96	96	96
2	3	100	100	100	100
2	3[1]	100	100	100	100
Check	—	0	0	0	0
3	1	46	46	48	48
3	2	100	100	100	100
3	3	100	100	100	100
3	3[1]	100	100	100	100
Check	—	0	0	0	0

[1] 27 inch vacuum applied before removal from fumigation chamber.

In our experiments, the check and treated plants were set out in the field on April 10, 1940 and observations on plant growth were made at frequent intervals. As the season progressed, it was noted that the plants treated at higher dosages and longer time exposure exhibited better growth than those of the checks. Since the apparent differences were marked, an attempt was made to compare the differences in the growths of the various lots.

In late August, data were taken on the

[2] Smith, L. M. Unpublished manuscript. On file at Univ. of Calif. Deciduous Fruit Station, San Jose, California.

production of runners by counting the runners of 15 plants selected at random. After irrigating the field, ten plants were dug out at random from each lot with the soil attached to the roots and were then set in vats filled with water, to soak, thus facilitating the removal of the soil from the roots with the aid of a water hose. The cleaned plants were placed between moist burlap sacks to take up the excess water. All runners were removed from the plants prior to weighing. The results are presented in table 2.

Table 2.—The effect of methyl bromide fumigation on the growth of Banner and Nich Ohmer strawberry plants. Temperature 72–74° F.

Lb./1000 Cu. Ft.	Exposure, Hours	Total Plants Treated	Ave. Runners per Plant	Ave. Wt. Foliage per Plant	Ave. Wt. Roots per Plant
		Banner Strawberry			
2	1	20	3.6	43.7 gms.	16.8 gms.
2	2	20	3.8	45.7	18.8
2	3	20	4.3	62.8	24.2
2	3[1]	100	4.1	70.5	21.6
Check—untreated		50	3.2	43.1	17.9
3	1	20	3.2	49.5	18.4
3	2	20	4.1	54.9	24.6
3	3	20	6.4	69.9	26.7
3	3[1]	100	5.1	70.0	30.4
		Nich Ohmer Strawberry			
2	1	20	2.3	19.9 gms.	6.1 gms.
2	2	20	3.1	20.5	6.3
2	3	20	3.3	18.1	6.6
2	3[1]	100	4.6	19.4	5.1
Check—untreated		50	2.5	14.3	6.3
3	1	20	2.8	15.0	5.9
3	2	20	3.6	15.6	6.0
3	3	20	5.0	26.7	8.9
3	3[1]	100	5.4	23.2	7.6

[1] Plants packed in crates with moist sphagnum moss; 27-inch vacuum applied before removal from fumigation chamber.

In the case of the Banner plants, there was an increase in the number of runners produced and an increase in the weight of the plants as the concentration of the methyl bromide and the time of exposure were increased. The effect on the Nich Ohmer plants was primarily in the stimulation of the production of runners. It was of interest to note, in the Nich Ohmer variety, where the average number of runners per plant on the check exceeded that of the avergae number of runners for the plants treated at 2 pounds per 1000 cu. ft., only 5 per cent of the runners in the former were established, whereas 95 per cent of the runners from treated plants were established.

Plants tested with atmospheric fumigation grew normally when treated at 1, 2, and 3 pounds of methyl bromide per 1000 cu. ft. for 2-hour exposure. In one case, stimulation in growth was noted for *Fragaria chiloensis* which was treated 3 pounds of methyl bromide per 1000 cu. ft. Plants which were treated at 4 and 5 pounds per 1000 cu. ft. were injured and developed numerous dwarfed and twisted petioles.

DISCUSSION.—In the cultivation and care of the non-everbearing strawberry varieties in California during the first year, the flower or fruit stems are removed in most instances as they appear, in order to prevent a serious drain on the vitality of the mother plant. The object is to develop vigorous daughter plants. The stimulative effect of the methyl bromide gas for the two varieties tested may therefore be desirable for the early establishment of mother plants and subsequent production of runners from the mother plants.

The life history of *Paria canella* is such that only the adult stage is concerned during fumigation in early spring. Since all the beetles dissected to date have proved to be females, the parthenogenetic nature of the insect makes it imperative that all beetles be destroyed on the planting stock.

SUMMARY.—*Paria canella* var. *quadrinotata* (Say) is a serious pest of strawberries in northern California. Its control on dormant planting stock may be effected by methyl bromide used at a rate of 2 pounds per 1000 cu. ft. for a 3-hour period or 3 pounds per 1000 cu. ft. for 2 hours, at a temperature of 72–74° F.

Definite stimulation in growth was noted for the treated plants as compared to those of untreated plants.

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The Distribution of Sodium Arsenite and Diluent in the Dust Cloud[1]

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The application of various insecticides in the form of a dust, which generally consists of the active ingredient plus a diluent or carrier as these are sometimes called, brings out some interesting problems. These have been of special interest in the Rocky Mountain states during the past few years owing to the fact that hundreds of tons of mixed dusts have been used in Mormon cricket control campaigns. The dusts most commonly used consist of commercial sodium arsenite plus diatomaceous earth in the proportion of one part of arsenite to three parts of earth, or sodium arsenite plus hydrated lime in the proportion of one part of arsenite to four parts of lime. Erratic results which were sometimes obtained in the field were often attributed to the quality of the dusts, the inference being that the diluent in some way decreased the effectiveness of the sodium arsenite. It is important to note that this toxic agent when used for the control of Mormon crickets has been shown to act as both a contact and stomach poison.

In decreasing the effectiveness of any toxic agent the diluent might enter into a chemical reaction with the active ingredient thereby decreasing its toxicity, or it might act in a purely physical manner coating the active material in such a way that a large part of it is kept from contact with the insect body.

Since a great many diluents in combination with sodium arsenite were being tried experimentally against the Mormon cricket, it was deemed advisable to obtain some information as to their effect if any on the toxic agent. It was not possible to demonstrate that there was any chemical union between the toxic agents and the diluents under the usual conditions of field application; therefore emphasis was placed on the physical reactions of the materials.

To date we have found no satisfactory method for studying the coating of one material by another where both are the same color. Optical methods were attempted but did not prove to be workable owing to the small amount of materials which had to be examined.

That an attraction exists between different materials has been demonstrated by using naturally colored particles of various sizes. The method of artificially coloring one material cannot be used in these studies because the surface of the particles may be changed by the dye. Most inorganic particles possess a negative charge on their surface and would not therefore be expected to have any affinity for each other. If a positively charged dye were adsorbed on one of the particles, conditions would be changed. The affinity existing between the particles of the materials used in the experiments reported here may be due to a surface film of moisture rather than any electrical effect.

A number of dust mixtures were investigated in an attempt to obtain one in which the individual particles could be identified under the microscope. The only combination which could be studied in this manner was one of volcanic ash and sodium arsenite. Both of the above materials were subjected to repeated fractionation until uniform samples were obtained. The two sodium arsenite fractions obtained had an average particle diameter (as determined with an ocular micrometer) of 40 microns and 2 microns respectively. Two samples of volcanic ash, one an average particle diameter of 30 microns and the other 9 microns were also obtained. Combinations of dusts were then mixed at the rate of three parts of volcanic ash to one part of sodium arsenite and examined under the microscope. It was observed that when the fine ash was mixed with the coarse arsenite it completely coated the arsenite but when the coarse ash was mixed with the coarse arsenite no coating of one material by particles of the other was observed. Likewise, when the fine sodium arsenite was mixed with the coarse ash, the particles of ash were completely coated by the arsenite.

When these mixtures were discharged from a dust nozzle and allowed to settle on a glass slide, it was found on examination that the agglomerates had broken up,

[1] Contribution from Montana State College, Agricultural Experiment Station, Journal Series No. 152.

each dust settling as individual particles. This demonstrates that the attraction between the particles in the original agglomerates was very slight and may have been due to surface moisture, as it was noted that many of the small arsenite particles took up sufficient moisture to change their appearance under the microscope entirely.

from a stationary apparatus which was held two feet above the floor in a horizontal position. The nozzle employed was constructed on the Venturi principle, the air being supplied from a tank which maintained a constant pressure of 5 pounds per square inch. The dusts were fed into the nozzle from a vibrating hopper, insuring an even flow of materials.

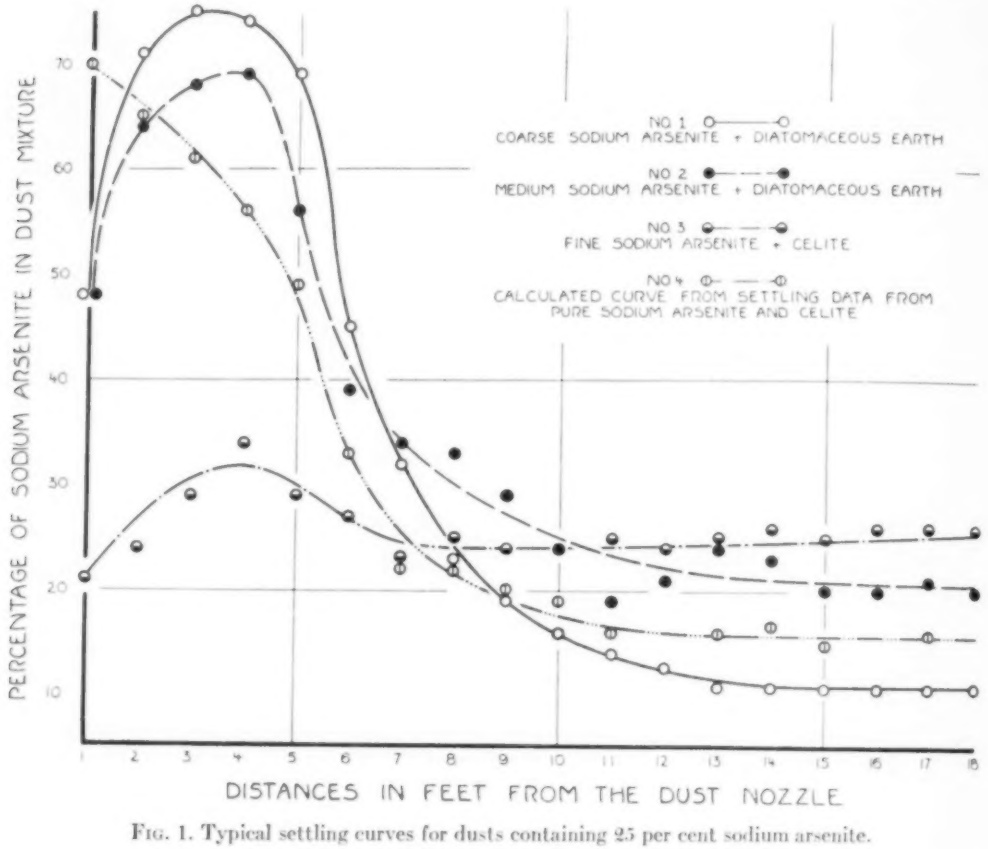
NO. 1
COARSE SODIUM ARSENITE + DIATOMACEOUS EARTH
NO. 2
MEDIUM SODIUM ARSENITE + DIATOMACEOUS EARTH
NO. 3
FINE SODIUM ARSENITE + CELITE
NO. 4
CALCULATED CURVE FROM SETTLING DATA FROM PURE SODIUM ARSENITE AND CELITE
PERCENTAGE OF SODIUM ARSENITE IN DUST MIXTURE
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
DISTANCES IN FEET FROM THE DUST NOZZLE

FIG. 1. Typical settling curves for dusts containing 25 per cent sodium arsenite.

A series of experiments were then instituted to determine the constitution of a number of mixed dusts[2] after being discharged through a nozzle. The dusting experiments were carried out in an especially constructed tunnel which was 40 feet long, 5 feet high, and 4 feet wide. It was covered with tar paper with all bracings on the outside to reduce eddying currents. Both ends of the tunnel were covered with several layers of cheesecloth to prevent drafts from sources other than from the nozzle. The dust was expelled

[2] Some of the samples of mixed dusts were prepared by the Division of Insecticide Investigations, U. S. Bureau of Entomology and Plant Quarantine.

Petri dishes having an area of 12.5 square inches were placed at 1-foot intervals along the floor and used to collect the dust mixtures which were to be analyzed. These dishes extended only over a distance of 18 feet from the nozzle, as beyond this point the amount of sodium arsenite recovered was too small for accurate analysis unless an excessive amount of material was discharged through the gun.

Two sets of tests were conducted, the first on the pure unmixed materials, which was solely of a quantitative nature, and the second on the mixed dusts which was

both quantitative and qualitative. The diluents investigated were diatomaceous earth, celite, talc, bentonite, calcium carbonate, hydrated lime, and volcanic ash.

The settling curves obtained for all the pure materials showed that settling was directly proportionate to particle size. Three typical settling curves for mixed dusts containing 25 per cent sodium arsenite are shown in figure 1. Curve 1 is that of coarse sodium arsenite (average particle size 13 microns) and diatomaceous earth (average particle size 1.2 microns[3]). At three feet from the nozzle the dust sample collected contained approximately 75 per cent sodium arsenite; at five feet, 69 per cent; at eight feet, 25 per cent, and at 13 feet, 11 per cent. In this case the bulk of the sodium arsenite had fallen out before the diatomaceous earth had settled in appreciable quantities. Curve 2 was obtained from a dust of medium sodium arsenite (average particle size 4 microns) and the same diatomaceous earth (average particle size 1.2 microns[3]). As with the previous dust the greater part of the sodium arsenite settled out within the first eight feet, but there was a larger per cent of sodium arsenite in the cloud beyond this point than in curve No. 1. Curve 3 was obtained from a dust of fine sodium arsenite (average size 2 microns) and celite with an average particle size of less than 1 micron.[3] In this case both materials settled out more uniformly throughout the distance investigated than was the case in either of the previous two. Curve 4 was obtained by blowing medium sodium arsenite alone into the tunnel, collecting samples, and weighing them, repeating the process with an equal amount of celite, and then multiplying the weights of the celite samples by three to obtain the 1 to 3 ratio of the mixed dusts. From these data the per cent sodium arsenite was computed. The similarity between this curve and those obtained from the coarse and medium sodium arsenite mixture (curves 1 and 2) is much greater than it is to curve 3.

The densities of these materials are: sodium arsenite 3.44, diatomaceous earth 1.96, and celite 1.99. It would appear, then, that these materials settle out according to certain physical properties, there being very little, if any, interaction between the constituent dusts. This is further brought out from a comparison of the quantitative data obtained from the mixed and unmixed material listed in table 1. These percentages represent a ratio between the total weight of all samples, taken at one-foot intervals for 18 feet, and the deposits of all stations up to and including the one being considered. Since these weights represent only a small fraction of the total dusts discharged, and since it was shown in figure 1 that the bulk of the diluent was carried out beyond the sodium arsenite, it can be seen that comparisons in the table can be drawn only between the same materials when expelled either singly or in a mixture. A marked similarity is noted between the percentages of sodium arsenite from the mixed and unmixed material deposited at the various intervals. This similarity will also be noted for the celite. The data show that the greater part of the sodium arsenite in the 18-foot sample area settled out within the first ten feet. Furthermore, it was noted that when the mixture of sodium arsenite and diatomaceous earth was used, what appeared to be a uniform dust cloud prevailed throughout the tunnel, but this evidently was not the case, as analyses of samples clearly showed.

It was concluded from these studies that no interaction took place between the

Table 1.—The percentage deposition of sodium arsenite and diatomaceous earth at the distances noted.

MATERIAL	DISTANCE IN FEET FROM DUST NOZZLE									
	1	2	3	4	5	6	7	8	9	10
Pure sodium arsenite	5.6	20.1	42.4	66.8	81.2	87.7	90.6	92.2	93.6	94.4
Mixed sodium arsenite	1.2	7.6	25.1	58.5	84.5	92.3	95.5	96.8	97.6	98.0
Pure celite	2.0	8.8	21.3	37.8	50.6	62.3	69.7	74.6	79.3	83.0
Mixed celite	1.8	5.3	13.5	28.8	44.6	57.6	66.6	72.8	77.2	80.4

[3] As stated by the manufacturer.

diluents and the active ingredient used, and further that the composition of a dust cloud obtained from the use of the above mixed dusts is dependent upon particle size. However, if densities of the materials in a dust mixture varied considerably this, as well as particle shape, would have to be considered.—7-23-41.

The Control of Black Scale in Olive Orchards by Calcium Cyanide Dusting

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Olive trees approximating 20,000 acres or 82 per cent of the commercial plantings in the United States are located in the San Joaquin and Sacramento Valleys of California. About one-half of the total domestic olive crop is produced in Tulare, Fresno, Kern and Kings counties.

Black scale, *Saissetia oleae* (Bern.) has been present in scattered locations in this area during the past 25 or 30 years, but not until recent seasons has it become sufficiently abundant to be seriously damaging in commercial plantings. It is of interest to note that, in this area where citrus fruits are growing contiguous to olive trees which are very heavily infested with black scale, this scale has not become established or perpetuated itself on citrus trees.

High summer temperature in this area has been considered the principal factor limiting the abundance of black scale. During the past several years, the scale has rapidly increased and spread, becoming so abundant in many orchards that, if uncontrolled, it has reduced the yield of the trees to a fraction of their normal production. This increase in black scale population may be attributed to two factors: first, summer seasons during which there have been few prolonged periods of excessively high temperatures; second, the fact that an improvement in the domestic olive industry, with increased income to the growers, has stimulated a change in cultural practices in a considerable portion of the olive acreage. This change has included heavier and more frequent irrigation, orchard fertilization resulting in increased foliage vigor and density, and decreased tree pruning. These conditions are all thought to be favorable to the survival of black scale during the warmer periods. It is the belief of many that high summer temperatures may again afford at least a temporary relief from this scale pest.

The increasing demand for effective control treatments, together with earlier experiences in the fumigation of olive trees in Spain, prompted our investigation of the possibility of utilizing fumigation with hydrocyanic acid gas as a practical means of control.

Our recent black scale investigations involved the study of dosage and exposure values. These included several extensive series of citrus tree fumigations in which black scale were simultaneously fumigated with the conventional citrus tree dosages and with greatly reduced dosages, and with exposures of 45 minutes compared with 20 and 25 minutes. These experiments were conducted in Orange and Ventura counties where the black scale passes through two generations each year.

Scale kills from the lower dosages were generally 99 per cent or above, though they were below those from the full dosages. Exposures of 45 minutes resulted in no increase in kill over 20 and 25 minute fumigations with like dosages.

The classification of the scale, according to stages, repeatedly showed that the stage of development at the time of treatment was of much greater influence upon resulting control, than were the wide differences in dosages tested.

The black scale infesting the olive trees in Central California develops only one generation each year, the major portion of the hatch occurring during the latter half of May and through the month of June. The young remain relatively small, apparently developing very slowly during the summer and early fall season.

In August 1939, two large Manzanillo trees in central Tulare County were fumigated with calcium cyanide (*Cyanogas*) applied under tents. One received a normal citrus tree dosage, the other approximately a half dose. The work was done

[1] American Cyanamid & Chemical Corporation, Azusa, Calif.

on a warm calm night. No live scale could be found on these trees when inspected three weeks later. In an effort to determine the natural mortality on untreated trees it was found necessary that samples be taken from trees somewhat removed from the two that were fumigated. It was then apparent that the gas escaping from the tents during fumigation had killed a considerable portion of the insects on the adjacent trees.

Late in November of the same year, an olive orchard located near Exeter, in Tulare County, was selected for more extensive trials. The trees were large and very heavily infested with black scale. Four trees were covered with tents of light cotton fabric. Calcium cyanide was applied under these, at a range of dosages from the standard citrus schedule downward to one-eighth dose. An effort was made to repeat this on four rows of trees. Three and a half sets were covered when a tent pole was accidentally broken, thus stopping the work. All trees received a fumigation exposure of 45 minutes.

Scale counts were made four weeks later These are shown in table 1.

Table 1.—Black scale control on olive trees by tent fumigation, November 20, 1939.

DOSAGE	TOTAL SCALE	NUMBER ALIVE	PER CENT DEAD
100%	12,000	30	99.75
50%	9,000	13	99.85
25%	9,000	24	99.73
12½%	9,000	28	99.69

The differences in kill between dosages were not significant. Again it was observed that the scales surviving treatment were in the more advanced stages of development. These results indicated that good commercial kills might be obtained, even in the late season, with relatively low concentrations of hydrocyanic acid gas. This suggested the possibility that a satisfactory control of the black scale might be accomplished by open dusting with calcium cyanide during calm midsummer nights.

OPEN-AIR FUMIGATION METHOD.—Early in the season of 1940, trials were made in an effort to fumigate infested trees by enveloping them in moderate concentrations of hydrocyanic acid gas, by rapidly distributing calcium cyanide dust throughout a block of trees. Obviously, this could be accomplished only during periods of near atmospheric calm. It was known that such atmospheric conditions occur most frequently in that area during summer nights following relatively high day temperatures.

A two and a lfalf acre block of large Manzanillo trees, located east of Exeter, California, was selected for the first trial. The trees were heavily infested with black scale. The hatch had started about May 1. On June 11 it was estimated to be approximately 70 per cent complete. That evening, 100 pounds of calcium cyanide (*Cyanogas A-Dust*) was applied at the rate of 40 pounds per acre. Application was made by a duster mounted on a rubber-tired tractor operated by a driver who wore a suitable gas mask. The duster was driven through the orchard at a speed of approximately 5 miles per hour. It was operated through every alternate space between tree rows, each trip through being spaced by 48 feet. The discharge of dust was directed upward into the trees, the cloud of dust enveloping the trees from the ground to near the tree tops. Approximately 5 minutes were required to treat the two and a half acres. The main cloud of dust remained in the orchard about 10 minutes. It gradually drifted to the southwest and had nearly all left the orchard by the end of 15 minutes.

Table 2.—Black scale control by open-air fumigation with calcium cyanide dust, June 11, 1940.

	TOTAL SCALES	NUMBER ALIVE	PER CENT DEAD
UNTREATED AREA:			
Lower portion of trees	1256	877	30.2
Upper portion of trees	368	256	30.4
TREATED AREA:			
Lower portion of trees	2000	38	98.1
Upper portion of trees	2000	141	93.0

Scale counts were made in this orchard one month after the treatment. Samples were collected from the trees at locations from 4 to 7 feet above ground level, and from the tops of the trees at a height of 18 to 20 feet. The resulting data are shown in table 2.

A large percentage of the live scale observed probably hatched subsequent to treatment. Recent observations in this orchard indicate the scale to be in a good

state of control. The majority of the black scales which hatch after the middle of June in this area are unable to survive the influence of usual summer weather

During the evening of June 26 the north half of a ten-acre block of large olive trees, proximately 10 minutes. The cloud of dust (gas) enveloping the trees drifted and cleared from the northeast corner of the 10 acres in approximately 20 minutes and from the southwest corner of the 10 acres 42 minutes after the start of the applica-

FIG. 1.—Calcium cyanide duster mounted on tractor and powered by tractor motor.

located south of Exeter, was similarly treated. In this work two power dusters were operated simultaneously. One of these dusters is shown in figure 1. The treatment of this five acres required ap-

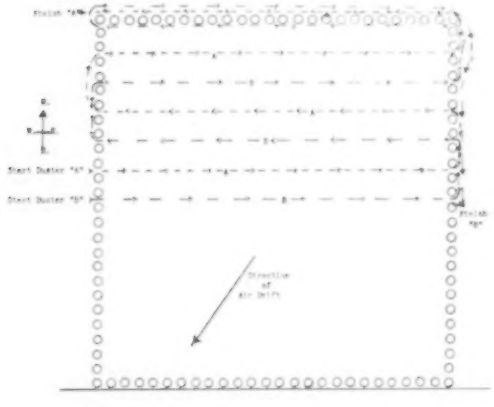

FIG. 2.—Route followed by dusters to quickly envelop a large orchard area within a "blanket" of calcium cyanide dust. The operation was completed by drifting dust into the trees from the north and east borders. June 26, 1940.

tion. Figure 2 illustrates the route over which the dusters were operated in this orchard. Considerable scale hatch was observed on treated trees four days after this treatment. Data on scale counts made on July 11 and 12 are shown in table 3.

Following this treatment the trees made a heavy foliage growth. Observations in June, 1941, showed the orchard to be lightly to moderately infested with scale and the trees to be carrying a heavy new

Table 3.—Black scale control by open-air fumigation with calcium cyanide dust, June 26, 1940.

	Total Scales	Number Alive	Per Cent Dead
AREA WELL REMOVED FROM TREATMENT:			
Lower portion of trees	886	500	43.6
Upper portion of trees	713	500	29.9
COMPOSITE COUNTS IN TREATED AREA:			
Lower portion of trees	10632	238	97.8
Upper portion of trees	8729	1080	87.6

crop of olives, their first in several years.

By the middle of July, 1940, the hatching of scale was considered to be complete in most orchards in the area. During the evening of July 20, a test was applied on a three-acre portion of an orchard of large trees located southwest of Lindsay, in Tulare County. One power duster was operated applying 180 pounds of dust over a period of 10 minutes. The material was used at the rate of approximately 60 pounds per acre. All of the dust had drifted from the orchard within 30 minutes after the start of the application.

Scale samples from random locations within the treated area and from an untreated portion of the orchard were examined on August 5. This data is presented in table 4.

Table 4.—Black scale control by open-air fumigation with calcium cyanide dust, July 20, 1940.

	Total Scales	Number Alive	Per Cent Dead
Untreated Area:			
Lower portion of trees	930	500	46.2
Upper portion of trees	813	500	38.2
Treated Area:			
Lower portion of trees	2790	17	99.4
Upper portion of trees	2439	18	99.3

The encouraging results obtained in these experiments led to a limited commercial use of this method during the balance of the 1940 season. Seventeen properties, or an aggregate of 200 acres, being so treated. These were located from Orange Cove on the north to Strathmore on the south, a distance of about 50 miles. Treatments were applied at intervals throughout the period from July 16 to Sept. 7.

All of these properties were inspected during the early summer of 1941. The effectiveness of the treatments was readily appraised at that time by the abundance of live mature scale on the twigs in relationship to the dead bodies that had remained throughout the preceding year (Fig. 3). On trees that were not treated during the 1940 season, the population had generally increased from ten to twenty times what it had been a year previously. In all but approximately 10 per cent of the treated acreage, the population was no greater, and generally less than it had been a year before. In some acreage the scale was so reduced that treatment during the 1941 season will not be justified.

The seasonal timing of treatments, between the middle of July and early

FIG. 3.—Mature black scale bodies on olive twigs at time of inspection in May 1941. The single twig at right was from untreated tree, luster of scale readily indicating them to be alive. Branch at left was from tree that was dusted in August 1940. Abundance of dead bodies, dull in appearance, compared to frequency of live individuals, indicated the reduction in population compared with the preceding season.

September, revealed no differences in effectiveness. In no instance was injury as a result of treatment observed in any orchard.

Air movement during the time of treatment was the most important factor influencing scale kill. In most instances where gas drifted from the trees within a few minutes after its application, there was a greater survival of insects. Where the trees remained enveloped in a cloud of dust for 20 minutes or longer, highly satisfactory kills resulted.

In all of the applications, other than in experimental plots, the material was used at the rate of approximately 40 pounds to the acre. Probably 40 pounds is the minimum dosage and 50 to 60 pounds per acre may actually effect the most economical control.

The average cost to the grower for com-

mercial treatment was $8.40 per acre. This included the cost of material and its application.

MANNER OF APPLICATION.—To obtain the highest concentration of HCN gas and to maintain a lethal concentration over the longest possible period from a given

FIG. 4.—Calcium cyanide duster, showing the loading of hopper by operator wearing a gas mask. This also shows the directional adjustment of the dust outlets.

dosage of dust, it is desirable to place a large area under dust in a minimum of time. In order that the dusters may be operated at high speed, the orchard soil should be worked smooth. Rough soil, deep open furrows and heavy weed growth, retard the normal operation. The length of run for the duster, through the block of trees, should be short so that large rectangular areas can be quickly placed under a blanket of gas.

It is not necessary to direct the dust discharge toward all parts of the trees, as it is the gas and not contact by the dust that kills the insects. The duster should be operated through every second or third space between tree rows, rather than in each space. By so doing, a large area can be placed under gas quickly, obtaining the maximum possible concentration of gas. Favorable atmospheric conditions for this work may include a slight drift. By treating a large area rapidly, even with a slight drift, sufficient exposure is obtained.

The work should be started on the side of the orchard toward which the dust will most probably drift. Since the duster is operated two or three rows (50 to 75 feet) into the air drift at each trip through the orchard, this enables the driver to work in an atmosphere that is free from gas.

This operating procedure is illustrated in figure 2.

The discharge from the duster should be directed upward and outward into the trees, otherwise the cloud created may remain stratified so close to the ground that the tree tops may escape a lethal concentration. The depth of the dust cloud can generally be governed by proper direction of the dust discharge. The arrangement of duster outlets and the controlled discharge of dust are shown in figures 4 and 5.

Invariably there is a cloud of fine dust in suspension in the air in any area con-

FIG. 5.—Calcium cyanide duster in operation, completing the dusting of an olive orchard by drifting dust into the border row.

taining a heavy concentration of gas. This serves as a helpful warning to operators. Duster operators must be equipped with gas masks. These should be used whenever they have occasion to enter an area that is under gas.

SPECIAL PRECAUTIONS.—This work

should be undertaken only by experienced and licensed operators who are familiar with the handling of hydrocyanic acid gas. They should always be equipped with gas masks provided especially for protection against hydrocyanic acid. They should have with them some experienced person to prevent anyone from entering the area that is under treatment. Before a treatment is started, thorough precautions should be taken to be sure that no persons are within such proximity to the orchard that they might be affected by the dust. In all of the work observed during the operations of the 1940 season, concentrations of HCN were essentially dissipated within 45 to 50 minutes after application.[1]—7-23-41.

[1] Much credit for the success of this work is due to Mr. Herman French, Deputy Agricultural Commissioner in Tulare County and to Mr. E. C. Moore, Assistant County Agent in that county. Mr. French took a leading part in conducting many of the experiments. Both he and Mr. Moore obtained the cooperation of numerous growers in whose orchards these trials were made. They assisted in the direction of the work and in checking the results accomplished.

The Behavior of Hydrocyanic Acid Gas Under a Fumigation Tent

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It was observed, in field studies conducted at the Whittier, Calif., laboratory over a period of several years, that there was a wide variation in concentrations of the gas in adjacent citrus trees fumigated under tents with hydrocyanic acid gas for the California red scale, *Aonidiella aurantii* (Mask.), although the gas was released with the same apparatus. The concentrations were also found to vary at different points under the same tree. The results suggested faulty introduction or distribution of the gas within the tent.

In studies with hydroycanic acid in a gastight box the authors observed that the time required for the gas to diffuse and reach a uniform concentration in all locations within the enclosure was much longer than was generally assumed to be the case. These results were obtained in the absence of foliage, which might obstruct the rapid diffusion of the gas. Such obstruction, as occurs under a regular fumigation tent, would give very high concentrations of gas in certain locations while in others the concentration would not be sufficient for a satisfactory control of the scale insects.

Further studies of the distribution of this gas in fumigation tents was therefore undertaken. Three types of fumigation were included—the method now in practice, that is, the use of vaporized liquid hydrocyanic acid, and two methods that have been discarded, namely, the pot method of fumigation and the application of atomized liquid hydrocyanic acid. These methods and their history have been reviewed by Quayle (1938).

EXPERIMENTAL PROCEDURE.—In order to have a constant volume for the experimental fumigations, a form was constructed over and around an orange tree (Fig. 1). The form, which was made of half-inch galvanized pipe braced with wire, was 14 feet high and 16 feet in diameter at the bottom, enclosing a volume of about 2,100 cubic feet. An ordinary commercial-type fumigation tent of 8-ounce duck canvas was used to cover the form.

Leads of small copper tubing were run from a number of places within the tent to the outside, for the purpose of withdrawing samples to determine the concentration of the gas at those points. The locations of leads from which the samples were drawn are shown in figure 1 and also listed in the key to the figures. The locations referred to as on the edge (*e.g.*, "8 feet east edge") were 1 to 2 inches from the tent fabric on the indicated side of the tree. "Top of tent" was about 1 foot below the top of the form in the center, above the foliage; "top of tree" was about 3 feet lower in the foliage; and "6 feet center" was attached to the trunk of the tree. The other locations (*e.g.*, "ground east" and "8 feet east") were on the indicated side, about 4 feet from the form. The terms "6 feet," "8 feet," etc., refer to the height above the ground. The concentrations for a single fumigation were de-

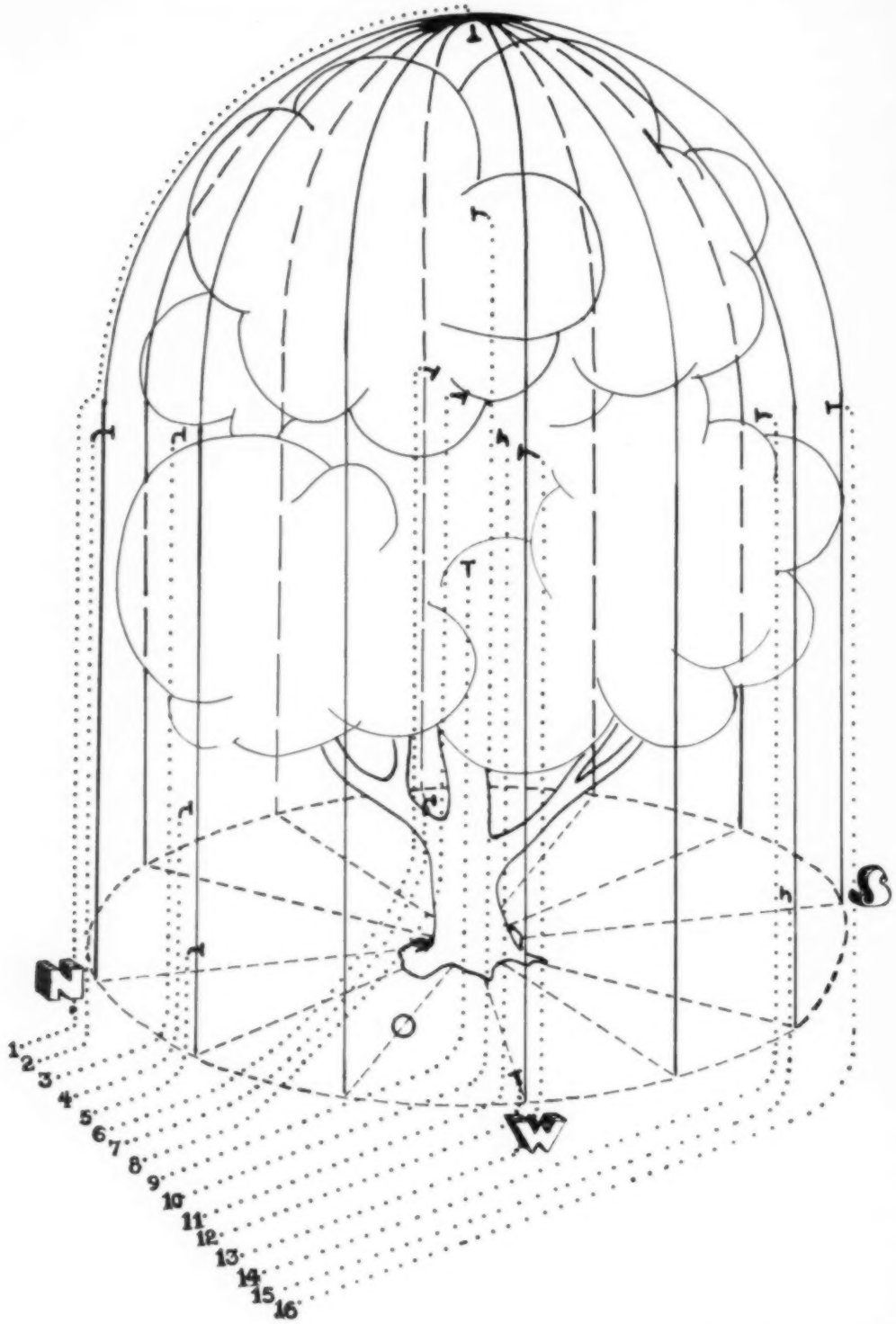

FIG. 1.—Illustration of form and location of sampling tubes used in the study of the distribution of hydrocyanic acid gas. Numbers of leads are explained in the accompanying key.

Table 1.—Analyses of samples of hydrocyanic acid gas from different locations within the form tent when the gas was produced by the pot method.

LOCATION	CONCENTRATION OF SAMPLE AT VARIOUS INTERVALS AFTER INTRODUCTION OF GAS, MILLIGRAMS PER LITER							
	Immediately	3 minutes	5½ minutes	8 minutes	11 minutes	15 minutes	20 minutes	25 minutes
8 feet east edge (6)	0.04	0.44	0.71	0.54	0.52	0.53	0.40	0.14
8 feet east (8)	1.42	3.55	1.86	1.28	0.91	0.67	0.53	0.37
6 feet south edge (16)	0.05	0.12	0.59	0.46	0.57	0.49	0.40	0.27
6 feet south (14)	0.03	0.59	—	1.20	1.11	0.89	0.59	0.50
Top of tent (1)	0.10	2.05	1.96	1.44	1.26	1.04	0.77	0.61
Top of tree (10)	0.08	0.75	1.35	1.41	1.25	0.96	0.79	0.55
6 feet center (9)	0.07	0.77	1.27	1.48	1.25	1.15	0.87	0.57
8 feet north (3)	0.04	1.32	1.72	1.27	1.08	0.87	0.63	0.50
2 feet north (4)	0.07	0.83	1.46	1.43	1.07	0.83	0.68	0.32
8 feet west (11)	0.02	0.72	1.45	1.73	1.54	1.19	0.94	0.72
Ground north (5)	0.06	1.21	1.67	1.34	1.15	0.87	0.69	0.48
Ground south (15)	0.04	0.67	1.14	1.30	1.05	0.80	0.68	0.44

termined in from 6 to 14 locations. The gas was introduced on the northwest side of the tree, at the point indicated in figure 1 by the small circle.

One-liter samples of gas were drawn by means of aspirators through an absorbing solution of 2 per cent sodium hydroxide. Samples were taken from all locations simultaneously, at intervals after the introduction of the hydrocyanic acid under the tent. The analyses were carried out later in the laboratory by titrating with standardized silver nitrate solution in the presence of potassium iodide, using a Tyndall light beam.

Unless otherwise stated, the dosage was equivalent to 18 cubic centimeters of hydrocyanic acid per 100 cubic feet, or a theoretical concentration of 4.51 milligrams per liter.

The leads used for analyses of hydrocyanic acid gas under the form tent are designated as follows:

(1) Top of tent
(2) 8 feet north edge
(3) 8 feet north
(4) 2 feet north
(5) Ground north
(6) 8 feet east edge
(7) Ground east
(8) 8 feet east
(9) 6 feet center
(10) Top of tree
(11) 8 feet west
(12) Ground west
(13) 8 feet west edge
(14) 6 feet south
(15) Ground south
(16) 6 feet south edge

Numbers refer to leads shown in figure 1 and to the curves for the respectve locatioins in figures 2 to 5. The distances refer to the height above the ground. Leads 2 and 13 are not referred to in the graphs but are mentioned in table 6.

FUMIGATION BY THE POT METHOD.—One of the common cyanide pots formerly used by commercial fumigators was secured for this work. A small metallic deflector was placed over the top of the pot to prevent the sulfuric acid from being carried into the tree. The sodium cyanide was added to previously diluted sulfuric acid at the rate of 1 ounce of sodium cyanide, 1.5 fluid ounces of sulfuric acid, and 2 fluid ounces of water, which was equivalent to an 18-cc. dosage of liquid hydrocyanic acid. The results of a liberation by the pot method are shown in table 1 and graphically in figure 2. It will be noted that with this type of liberation approximately five minutes was required for distribution of gas within the tent, and that the space near the periphery of the tent never reached a concentration comparable to that in the interior. This location was consistently low in every fumigation made by this method.

FUMIGATION WITH LIQUID HYDROCYANIC ACID.—In fumigation with liquid hydrocyanic acid the liquid is pumped in measured amounts from a cylinder directly to a nozzle, which is held under the tent. By this method the liquid is sprayed in several directions without the aid of heat. An example of a fumigation by the liquid method is shown in table 2 and graphically in figure 3. From the analyses it is evident that a large portion of the hydrocyanic acid remains as a liquid on the ground or is absorbed by the soil. The

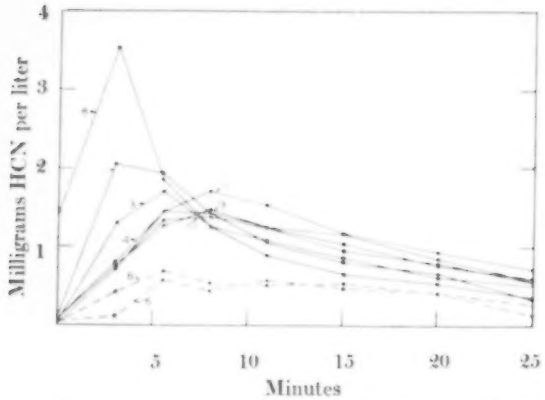

FIG. 2.—Concentrations of hydrocyanic acid gas within the form tent after a fumigation by the pot method.

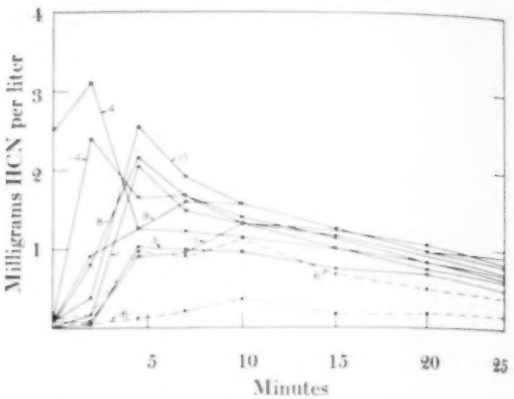

FIG. 3.—Concentrations of hydrocyanic acid gas within the form tent after a fumigation by the liquid hydrocyanic acid method.

Table 2.—Analyses of samples of hydrocyanic acid gas from different locations within the form tent when the gas was produced by the liquid method.

LOCATION	CONCENTRATION OF SAMPLE AT VARIOUS INTERVALS AFTER INTRODUCTION OF GAS, MILLIGRAMS PER LITER							
	Immediately	2 minutes	4½ minutes	7 minutes	10 minutes	15 minutes	20 minutes	25 minutes
8 feet east edge (6)	0.12	0.19	0.97	0.90	0.13	0.07	0.05	0.04
8 feet east (8)	0.06	0.80	2.19	1.68	1.41	1.13	0.83	0.70
6 feet south edge (16)	0.06	0.06	0.12	0.22	0.37	0.16	0.19	0.16
6 feet south (14)	0.08	2.46	1.65	1.69	1.35	1.16	0.89	0.72
Top of tent (1)	0.02	0.15	2.06	1.51	1.33	1.02	0.76	0.62
Top of tree (10)	0.11	0.39	2.58	1.91	1.58	1.25	0.98	0.81
6 feet center (9)	0.10	0.91	1.27	1.63	1.57	1.27	0.98	0.94
8 feet north (3)	0.02	0.05	1.04	0.99	0.98	0.76	0.70	0.50
2 feet north (4)	2.52	3.14	1.25	1.23	1.14	1.01	0.86	0.66
8 feet west (11)	0.11	0.10	0.90	0.96	1.30	1.22	1.07	0.86
Ground north (5)	13.31	7.27	1.63	1.40	1.24	1.00	0.87	0.73
Ground south (15)	11.42	5.59	2.16	1.72	1.41	1.10	0.91	0.71
Ground east (7)	8.94	5.46	2.09	1.77	1.58	1.27	0.98	0.80
Ground west (12)	—	—	21.55	4.01	2.22	1.59	1.07	0.87

Table 3.—Analyses of samples of hydrocyanic acid gas from different locations within the form tent when the gas was produced by the vaporized hydrocyanic acid method.

LOCATION	CONCENTRATION OF SAMPLE AT VARIOUS INTERVALS AFTER INTRODUCTION OF GAS, MILLIGRAMS PER LITER							
	Immediately	2½ minutes	5 minutes	8 minutes	10½ minutes	15 minutes	20 minutes	25 minutes
8 feet east edge (6)	2.28	0.92	0.70	0.60	0.57	0.41	0.21	0.33
8 feet east (8)	4.78	1.81	1.72	1.55	1.35	1.02	0.75	0.54
6 feet south edge (16)	0.33	0.19	0.18	0.15	0.11	0.13	0.05	0.07
6 feet south (14)	4.47	1.51	1.20	1.63	1.09	0.30	0.24	0.62
Top of tent (1)	6.17	3.01	1.84	1.65	1.39	1.01	0.71	0.58
Top of tree (10)	1.37	2.68	1.99	1.64	1.44	1.16	0.90	0.65
6 feet center (9)	1.30	1.85	2.00	1.78	1.44	1.12	0.87	0.64
8 feet north (3)	2.20	2.00	1.87	1.48	1.29	1.06	0.73	0.57
2 feet north (4)	0.20	1.49	1.75	1.33	1.16	0.95	0.76	0.48
8 feet west (11)	0.01	1.43	1.76	1.67	1.33	1.00	0.75	0.53
Ground north (5)	0.30	1.57	1.65	1.29	1.18	0.94	0.67	0.52
Ground south (15)	0.44	1.67	1.49	1.42	1.02	0.88	0.62	0.50
Ground east (7)	3.62	1.96	1.81	1.55	1.29	0.95	0.72	0.53
Ground west (12)	1.31	2.27	1.81	1.48	1.29	1.00	0.68	0.54

time required to reach equilibrium is practically the same as in the pot method. By this method also the concentration of gas near the periphery of the tent is much lower than that found within.

FUMIGATION WITH VAPORIZED HYDROCYANIC ACID GAS.—A typical fumigation with one of the commercial vaporizers now in general use is shown in table 3 and graphically in figure 4. The machine is similar to that used in the previous method, *i.e.*, the liquid hydrocyanic acid is pumped from the reservoir in measured quantities, but instead of the liquid being atomized in the tent, it is forced through a small flash boiler that is maintained at approximately 20 pounds' steam pressure. The temperature (260° F.) is sufficient to vaporize the liquid partially before it enters the nozzle. The concentrated gas is forced in several directions under the tent, but the time required to reach equilibrium within the unit is practically the same as with the former methods. Moreover, this method does not eliminate the places of low concentration near the periphery of the tent and in certain regions within the enclosed space.

DILUTION OF LIQUID HYDROCYANIC ACID.—In successive fumigations with the vaporizer spots of high concentration of hydrocyanic acid gas were always found at the top of the tent and on the side opposite to the point where the gas was released. Artificial carburetion and dilution of the liquid with air before it reached the tent was tried. Large fans were placed within the tent to circulate the air-gas mixture, but this method of distributing the gas was found to be unsatisfactory because of the dense foliage. High-speed vane and propellor types of blowers were used afterwards to dilute the gas. The vane-type blower had a capacity of 2000 cubic feet of air per minute; that of the propellor type was much lower (300 cubic feet per minute), but it delivered the air at a high velocity. The blower was placed under the tent so that the air would be circulated without dilution by the entrance of outside air, and it was allowed to run for 30 seconds after the gas was released in the air stream. The sampling was started as soon as the gas was released. The results of a fumigation by the dilution method in which the high-speed vane-type blower was used are shown in table 4 and graphically in figure 5. It will be noted that the gas was detected in all locations immediately. It will also be noted that the area near the edge remained at the same concentration as the inner zone. No difference could be detected in the distribution obtained with the two types of blowers. Both appear to be adequate for distribution of the gas.

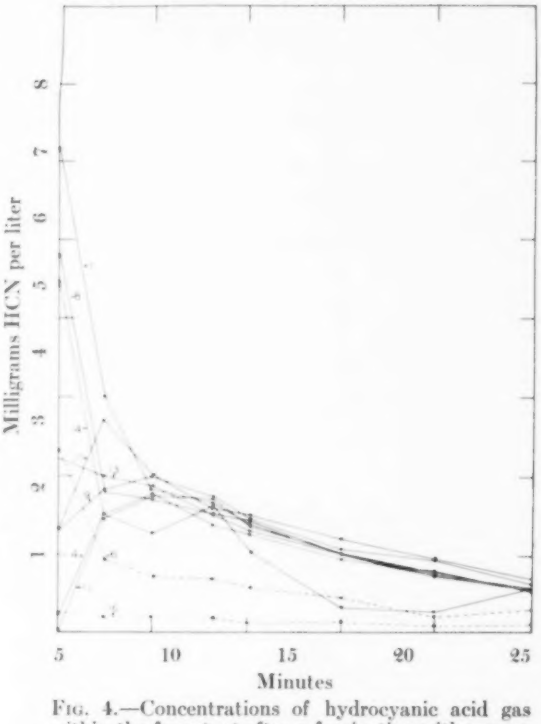

FIG. 4.—Concentrations of hydrocyanic acid gas within the form tent after a fumigation with vaporized hydrocyanic acid.

Experiments with the blower unit were also conducted in a lemon grove, where trees were covered with regular fumigation tents. Satisfactory distribution of the gas was obtained under these conditions.

BIOLOGICAL TESTS WITH AND WITHOUT BLOWER.—On two successive nights scale insects on lemons were placed near the copper-tubing leads to determine the relative mortality with and without the blower. Twelve lemon fruits infested with red scales (resistant strain) difficult to kill with hydrocyanic acid were placed in screen baskets at various locations under the tree, where gas samples were taken. On each fruit 50 scale insects in the second-molt stage of development were marked. The insects treated on each night were 20 days old and were reared simul-

Table 4.—Analyses of samples of hydrocyanic acid gas from different locations within the form tent when the gas was produced by the liquid method and diluted with a blower.

Location	Concentration of Sample at Various Intervals after Introduction of Gas, Milligrams per Liter							
	Immediately	2½ minutes	5 minutes	8 minutes	10½ minutes	15 minutes	20 minutes	25 minutes
8 feet east edge (6)	2.16	1.91	1.43	1.30	1.05	0.87	0.62	0.45
8 feet east (8)	1.70	2.22	1.78	1.34	1.32	1.02	0.72	0.55
6 feet south edge (16)	0.83	1.85	1.67	1.37	1.19	0.89	0.68	0.52
6 feet south (14)	1.95	2.11	1.75	1.44	1.20	1.11	0.72	0.56
Top of tent (1)	2.11	2.31	1.83	1.56	1.22	0.96	0.73	0.58
Top of tree (10)	2.45	—	1.40	1.47	1.20	0.89	0.66	0.55
6 feet center (9)	2.93	1.85	1.68	1.29	1.14	0.87	0.66	0.51
8 feet north (3)	1.86	2.05	2.22	1.62	1.35	1.09	0.83	0.62
2 feet north (4)	1.50	1.52	1.46	1.10	1.02	0.83	0.63	0.49
Ground north (5)	—	1.30	0.85	0.78	0.94	0.87	0.66	0.55
Ground south (15)	1.15	1.36	1.14	1.09	0.98	0.83	0.68	0.46

taneously at a constant temperature of 77° F. and a relative humidity of 65 per cent. The dosage of liquid hydrocyanic acid was 14 cubic centimeters per 100 cubic feet, or 3.51 milligrams per liter.

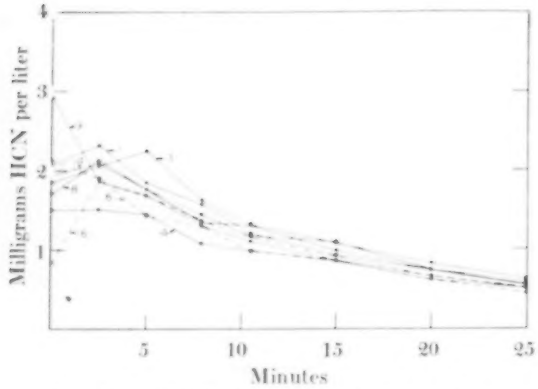

FIG. 5.—Concentrations of hydrocyanic acid gas within the form tent after a fumigation by liquid method and dilution with a blower.

Untreated checks showed no appreciable mortality during the 14-day interval between the treatment and the mortality count; so no correction was made for natural mortality. Without the blower the mortalities at the different locations under the tree were in general markedly different (table 5). With the blower the differences were not significant (differences exceeded by chance more frequently than once in 20 times) except in the one case in which the average concentration was 0.39 milligram per liter, where the percentage mortality was significantly lower than in the locations giving mortalities in the nineties (difference exceeded by chance less than once in 20 times). It is evident that the variations in mortality within the tent and near the periphery resulting from variable concentrations of gas were reduced by diluting the gas with the blower.

SUMMARY.—The behavior of hydrocyanic acid gas under a form tent over an

Table 5.—A comparison of mortalities and concentrations of hydrocyanic acid gas with and without dilution with air by means of a blower.

Location	Without Blower			With Blower		
	Per cent mortality	Concentration of Gas, Milligrams per Liter		Per cent mortality	Concentration of Gas, Milligrams per Liter	
		Average	Maximum		Average	Maximum
6 feet south (14)	99.7±0.2	1.24	5.50	87.3±2.9	0.67	1.41
8 feet south edge (16)	99.2±0.5	0.82	5.22	89.8±1.7	0.45	1.39
6 feet center (9)	90.2±1.4	0.85	2.06	93.3±1.5	0.59	1.39
8 feet north (3)	76.3±3.9	0.51	1.06	94.2±1.7	0.71	1.85
8 feet north edge (2)	56.8±2.0	0.16	0.25	93.5±1.0	0.62	1.72
8 feet west edge (13)	70.2±3.4	0.20	0.45	87.2±1.7	0.39	1.37

orange tree has been studied. The distribution of the gas was determined both with methods of liberation now in practice and with methods that have been discarded. It was found that all the methods produced locations of low concentration, especially near the periphery of the tent. The concentration of the gas varied sufficiently to produce significant differences in mortality of scale insects.

A method has been developed to reduce this variation by first diluting the hydrocyanic acid with air by means of a blower inside the tent. This improvement is supported by chemical analyses and by the tests of mortality of scale insects placed at several locations in the tent. Adequate distribution of the gas was also obtained with the dilution device when trees in a lemon grove were covered with regular fumigation tents.—7-23-41.

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Matsucoccus bisetosus Morrison,[1] a Potential Enemy of California Pines

HOWARD L. McKENZIE, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The importance of scales as injurious forest insects has been brought to light by recent studies conducted by the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture. Among the scales which stand out in the western region are those of the genus *Matsucoccus*, family Margarodidae, that confine their attacks to pines. The effect of these insects in the pine forests is definitely one of injury to twigs and branches, weakening of the crowns, and deformation of the younger trees. This has been recently substantiated by detailed studies of the Prescott scale, *M. vexillorum* Morrison, in Arizona.

In the California region a preliminary survey of the *Matsucoccus* forms indicates that there are a half dozen or more species that appear to be definitely connected with injury to pines, and of these *M. bisetosus* Morrison appears to be the most injurious. This preliminary paper presents fragments of information that have been accumulated on this species during the past 2 years. On the basis of this evidence the Bureau of Entolomogy and Plant Quarantine has undertaken further study of this scale problem.

EFFECT OF THE SCALE ON PINES.—*Matsucoccus bisetosus* attacks both young and mature ponderosa and Jeffrey pines in California forests. It infests the twigs,

[1] Homoptera: Margarodidae.

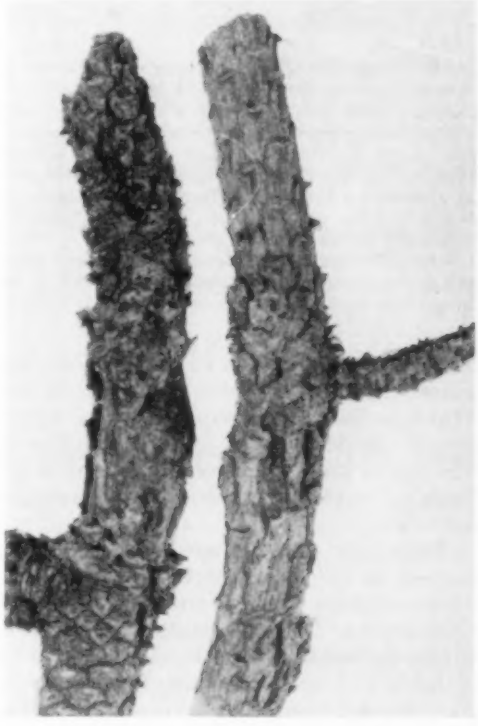

FIG. 1.—Stems of ponderosa pine collected from trees infested with *Matsucoccus bisetosus* near Middletown Lake County, Calif. The cracking and roughening of the bark is apparently associated with infestations of the scale. Resining is also noted on infested stems, particularly in the branchlet crotches, where feeding scale insects are commonly found.

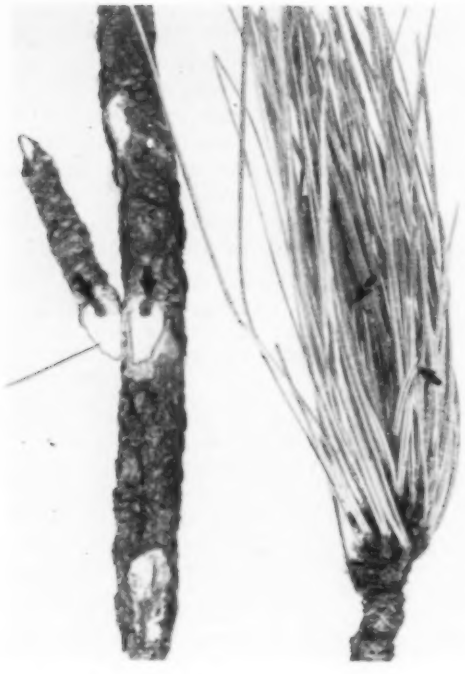

FIG. 2.—Left. Branch from a decadent mature ponderosa pine tree on the Black's Mountain Experimental Forest, Lassen County, Calif., infested with *Matsucoccus bisetosus*. The preadults of this scale are commonly found feeding in the branchlet crotches. In such crotches resining is usually present as globules on the bark surface and oftentimes extends into the cortex tissue. The arrows point to resining in one of these crotches.

Right. The current needles on these scale-infested stems are apparently much shortened, and it is believed that this may be the result of scale feeding.

branches, and trunks of trees of all age classes. On mature trees its attack on the trunk is limited principally to the upper crown. Bark cracking and roughening on the stems and branches is apparently associated with infestations of this scale insect (Fig. 1).

Preadults (larvae) are commonly observed in the crotches of branchlets. In these crotches much resining is evident as globules on the bark surface and oftentimes extends into the cortex tissue (Fig. 2, left). This crotch resining appears to retard normal physiological functions of the infested branch. Needle shortening and thinning of needle complement seem to be commonly associated with such injury (Fig. 2, right).

Apparently as a result of extended scale feeding on the stems and in the crotches of small branchlets, the branch ultimately flags or dies. The first evidence of a flagged branch is the gradual fading of the foliage to a pea-green color and then, as the season progresses, to a deep sorrel (Fig. 3). Flagged branches are conspicuous at first, but as the season continues and the needles fall off they become less noticeable.

WHERE THE SCALE OCCURS.—Infestations of *Matsucoccus bisetosus* appear to be rather general throughout the pine stands of California and Oregon. Outstanding collection records pertaining principally to injury produced by the scale are listed in table 1.

POTENTIALITIES AS A FOREST PROBLEM.—So far as preliminary observations go, it would seem possible that this scale insect may be one of the important factors in the decadence of the mature ponderosa pine and Jeffrey pine forests which supply the California lumbering industry. One can readily visualize how *Matsucoccus bisetosus* infestations on the branchlets and stems might contribute to the decadence of mature pines. The gradual killing

FIG. 3.—A mature Jeffrey pine tree at Pine Valley San Diego County, Calif., infested with *Matsucoccus bisetosus*. The gradual killing of the branches by the feeding activities of this scale insect ultimately puts the mature pines in a state of decadence, and this type of tree appears to be more susceptible to bark beetle attack. Photo by J. M. Miller.

Table 1.—Occurrence and effects of *Matsucoccus bisetosus*.

LOCALITY AND HOST	DATE AND COLLECTOR	INJURY
On *Pinus ponderosa:*		
Hat Creek, Shasta County, Calif.	Aug. 23, 1938 H. L. McKenzie	(1) Needle complement reduced. (2) Branchlet crotches resined. (3) Juvenile trees flagged.
Burns, Ore.	Nov. 26, 1938 T. Kachin	(1) Needles short and pale. (2) Twigs with cankerlike swellings. (3) Lateral leaders on young to middle-aged trees deformed.
Middletown, Lake County, Calif.	Aug. 24, 1939 H. L. McKenzie	(1) Needle complement reduced. (2) Branchlet crotches resined. (3) Flagging. (4) Mature trees subsequently attacked by bark beetles[1]
Black's Mountain Experimental Forest, Lassen County, Calif.	Oct. 1939 J. W. Bongberg J. M. Miller	(1) Needle complement reduced. (2) Current needles shortened. (3) Branchlet crotches resined. (4) Flagging. (5) Mature tree subsequently attacked by bark beetles.[2]
Black's Mountain Experimental Forest, Lassen County, Calif.	Nov. 7, 1939 H. L. McKenzie	(1) Needle complement reduced. (2) Current needles shortened. (3) Branchlet crotches resined. (4) Mature trees flagged.
On *Pinus jeffreyi:*		
Pine Valley, San Diego County, California	Nov. 10, 1939 J. M. Miller S. T. Carlson	(1) Branchlet crotches resined. (2) Mature trees flagged.
Cuyamaca State Park, San Diego County, California	Nov. 11, 1939 J. M. Miller	(1) Stems with abnormal adventitious buds developed. (2) Mature trees flagged.

[1] *Ips confusus* Lec. and *Dendroctonus brevicomis* Lec.
[2] Branches infested with *Matsucoccus californicus* and either *secretus* or a new species, as well as *bisetosus*, which was the most abundant.

of the smaller branchlets and stems would ultimately lead to the killing of large branches. The reduction of the needle complement as a result of scale activity would no doubt influence tree vigor, and it seems reasonable to assume that such weakened trees would be much more susceptible to bark beetle attack than healthy trees.—7-23-41.

A Morphological Difference Between the California Red Scale and the Yellow Scale

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For a long time the yellow scale, *Aonidiella citrina* (Coq.), was considered morphologically identical with the California red scale, *A. aurantii* (Mask.). However, after a comparative study of their ecology, biology, and morphology Nel (1933) recognized the yellow scale as a distinct species. McKenzie (1937), who concluded that the morphological differences pointed out by Nel were not always well defined, discovered sclerotized structures on the pygidium of the mature female red scale, which were not found on the yellow scale.

In both the California red scale and the yellow scale the mandibles and maxillae are closely joined to form a long, delicate feeding tube, termed the "rostralis" by MacGillivray (1921). In his discussion of coccids on palm trees Stickney (1934) stated that the length of the rostralis for any stage appeared to be of little generic,

Table 1.—Rostralis length of red and yellow scales in the various developmental stages.

Stage of Development	Length of Rostralis, Millimeters[1]					
	Red Scale			Yellow Scale		
	Average	Maximum	Minimum	Average	Maximum	Minimum
First	0.32	0.35	0.28	0.42	0.45	0.36
Second	1.08	1.23	0.85	1.51	1.76	1.32
Third	2.70	3.05	2.49	4.37	4.60	4.15

[1] Figures based on 20 scales.

but might be of definite specific, value. In the present study measurements were taken of the rostralis of the two scales, but no attempt was made to coordinate the measurements with the morphological differences pointed out by McKenzie.

The body of the insect was loosened from the host material with a metal pick and slowly and carefully lifted with a camel-hair brush, trimmed to produce a two-tined fork, until the rostralis was free from the host material. This was done with the aid of a binocular microscope giving a magnification of approximately 20×. Special care was taken to keep the rostralis intact.

After the rostralis was removed from the host the insect was placed on a rectangular coverglass (50 by 24 mm.) thinly coated with Mayer's albumen fixative. The distal end of the rostralis was placed in the adherent first and the threadlike feeding tube was kept taut as it was lowered into the adherent. The body was placed ventral side down. Several insects usually were placed on the same coverglass.

The coverglass with the mounted specimens was inverted and placed on a mechanical stage for microscopic measurement so that the point of attachment of the rostralis to the body could be clearly seen. Before measurement the rostralis was carefully examined at a high magnification (approximately 500×) to see that it was complete and none of its parts was broken.

The scales usually were obtained from green, turgid fruits, since they are more easily removed from this host than from leaves, twigs, or slightly soft fruits. The difficulty of removing the insects with the mouth parts intact is also decreased if the rind has been attacked by brown rot. The insect must be removed, however, before it has disintegrated.

It was found that the scales could be removed from fruits more easily if the rind was treated with a solution of sodium hyperchlorite or chloral hydrate. Small sections of the rind on which the scales were located were placed in a shallow dish with only the albido of the rind submerged. The scales were removed after the rind was broken down somewhat by the solution. (It is important that the solution does not cover the insects and kill them immediately, for after the insects are dead the rostralis breaks loose from the body even more readily.)

A large number of preliminary measurements were made of the rostralis of red and yellow scales taken from the field. The scales were designated as red and yellow by field workers, who distinguished them by differences in color, general appearance, habits, and geographical location. The red scales were on lemon fruits from Corona, Calif., and the yellow scales were on orange fruits from Redlands. The scales were in the first, second, and third stages of development. Those in the first and second stages were both males and females.

Table 2.—Rostralis length of mature female red and yellow scales reared in the laboratory and in the field.

Source of Scales		Length of Rostralis, Millimeters[1]		
Location	Grove	Average	Maximum	Minimum
Yellow scales reared on lemon fruits in the laboratory				
Ivanhoe	A	4.35	4.63	4.21
	B	4.28	4.63	3.90
	C	4.35	4.53	4.05
Redlands	D	4.54	4.79	4.37
Yellow scales on orange fruits fom the field				
Ivanhoe	A	4.20	4.58	3.79
		3.97	4.10	3.74
	B	3.96	4.21	3.74
Redlands	D	4.44	4.58	4.21
Red scales reared on lemon fruits in the laboratory				
Fallbrook	A	3.36	3.58	3.16
Corona	B	3.06	3.32	2.90
Redlands	C	3.16	3.42	2.90
Escondido	D	2.96	3.16	2.63
Ventura	E	3.22	3.47	2.79
San Fernando	F	2.98	3.16	2.68
Red scales on orange and lemon fruits from the field				
Redlands	C[2]	3.22	3.58	2.90
	G[2]	3.43	3.68	3.16
Whittier	H[3]	2.84	3.21	2.58
San Fernando	I[3]	2.82	3.10	2.53

[1] Figures based on 10 scales.
[2] Orange fruits.
[3] Lemon fruits.

males but those in the third stage were exclusively females. Rostralis measurements of the two scales are summarized in table 1.

The rostralis of the yellow scale was found to be longer than that of the red scale. Furthermore, the minimum length of this structure for the yellow scale was longer than the maximum length for the red scale.

Rostralis measurements of the two scales reared on leaves, twigs, and fruits from groves in different locations were made at different times throughout several years. There was considerable variation in the measurements, especially as to scales on leaves and fruit. For example, the rostralis length of 20 red scales on lemon leaves averaged 3.52 mm. and ranged from 3.26 to 3.84 mm., and that of 20 red scales on lemon fruits from the same location averaged 2.95 mm. and ranged from 2.74 to 3.26 mm. However, the average length for the yellow scales was always much greater than that for the red scales, regardless of the host.

Because of variation associated with the host, red and yellow scales from different groves in different localities were reared simultaneously on green lemon fruits in the laboratory and a number of the scales measured. Measurements were also made of scales from the field. The measurements of the mature female scales are summarized in table 2.

On the same host material the rostralis of the yellow scale was always longer than that of the red scale. There was, however, a little overlapping when red scales from leaves were compared with yellow scales from fruits. Other observations not given in detail in this paper have indicated that the ratios of the length of the rostralis to the size of the scale are significantly different for the two forms. These observations furnish further evidence of the present belief that the red and yellow scales are distinct species. Since on the average the rostralis of the yellow scale is much longer than that of the red scale, the length of this structure is suggested as a helpful character in distinguishing the two species when available material will permit. In the past the specimens have not been taken with the mouth parts intact, and therefore the character cannot be used to distinguish museum material.—7-23-41.

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Preliminary Experiments on the Silverfish *Ctenolepisma urbani* Slabaugh[1]

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The silverfish *Lepisma saccharina* L. and *Thermobia domestica* (Packard) are well known as household pests throughout the United States. A third and recently described species (Slabaugh 1940), *Ctenolepisma urbani* Slabaugh, is an important household pest in southern California. Where the infestation by this silverfish is severe, it causes some injury. It eats patches in wallpaper, removes the glaze from paper, and mars the binding of books. Valuable etchings and prints are disfigured by having the surface eaten away. *C. urbani* feeds upon textiles, especially when these are starched. As a rule, only those articles are severely damaged which have been undisturbed for some time.

Modern buildings but a few years old

[1] This paper is a contribution from the Entomologist for the Grounds and Buildings Department, University of California at Los Angeles.

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are often badly infested. It appears that the even temperature maintained throughout the year is favorable for the multiplication of *C. urbani;* moreover, ventilators and heat conduits, originating in the basement, facilitate the spread of the insect throughout the building, for it is usually the basement area of the home that is most badly infested.

In Los Angeles pest control operators, libraries, and private individuals resort to the use of poison cards in the control of silverfish. These cards, $2\frac{1}{4}\times4$ inches, are dipped in a paste consisting of 93 parts flour and 7 parts white arsenic by weight. Despite the use of these cards, silverfish and their injury are much in evidence. The following series of preliminary experiments were initiated in order to become better acquainted with the behavior of *C. urbani*, and to ultimately use this information for control purposes.

EXPERIMENT 1.—This test was conducted in order to determine whether or not the silverfish, *Ctenolepisma urbani*, feeds on the poison cards.

Ten poison cards and 10 cards coated with flour paste alone were placed at regular intervals beneath a badly infested auditorium so that one poison card was adjacent to one card with the flour paste alone.

At the end of 2 weeks the flour paste was almost completely removed from the unpoisoned cards. At the end of 6 weeks there was still no evidence of feeding on the poison cards other than on a small portion where the paste had not been spread. Apparently the insect is repelled by the poison cards.

EXPERIMENT 2.—A study was made of the preferences of this silverfish for some of the bait materials used as pastes in silverfish control.

Yellow chemical paper was cut into strips $2\times4\frac{1}{4}$ inches. Half of each strip was coated with a paste of one of the materials indicated below:

Beef extract, 2 grams; distilled water, 10 cc.; warmed.
Peptone, 5 grams; distilled water 20 cc.; warmed.
Gelatin (powdered), 5 grams; distilled water 20 cc.; warmed.
Sugar (crystal), 5 grams; distilled water 10 cc.
Wheat flour, 5 grams; distilled water, 10 cc.
Wheat flour, 5 grams; powdered salt, 0.2 grams; distilled water, 10 cc.
Wheat flour, 4 grams; powdered sugar, 1 gram; distilled water, 10 cc.
Salted crackers (finely ground), 5 grams; distilled water, 20 cc.
Starch, 5 grams; distilled water, 10 cc.
Glue (*LePage*)
Mucilage (*Sanford*)
Library Paste (*Sanford*)

Ten sets of these cards were then placed beneath the badly infested auditorium, and the amount of feeding was observed at weekly intervals. The temperature beneath the auditorium was fairly constant, ranging from 70° to 74° F. The amount of feeding was graded according to the following arbitrary method:

A.—Paste from two-thirds to completely removed; B.—Paste from one-third to two-thirds removed; C.—More than a few nibble marks to one-third removed; D.—A few nibble marks; E.—No feeding.

The results of this experiment are indicated in table 1.

Table 1.—Preferences of *C. urbani* for bait materials used as pastes based on an average of 10 cards tested for each material.

Food Ingredient	Ratings of Feeding			
	1st week	2nd week	3rd week	4th week
Beef extract	B	A	A	A
Peptone	D	B	A	A
Gelatin	D	C	B	B
Glue	C	B	A	A
Mucilage	E	E	E	E
Library paste	D	D	D	C
Sugar	C	B	B	A
Flour	B	A	A	A
Flour and salt	B	A	A	A
Flour and sugar	B	A	A	A
Salted cracker	C	B	B	A
Starch	C	B	A	A

CONCLUSIONS.—*Ctenolepisma urbani* feeds on materials of both animal and vegetable origin. Sweetman (1939) found that the silverfish *Lepisma saccharina* L. had similar feeding habits. Wheat flour, whether or not it contains sugar or salt, is extremely attractive to this silverfish; beef extract is likewise so. In descending order of perference, *C. urbani* fed upon the bait materials as follows:

Flour; flour and salt; flour and sugar; beef extract.

Ground salted crackers.
Peptone; starch.
Sugar; glue.
Gelatin; library paste.
Mucilage.

EXPERIMENT 3.—A study was made of the preferences of *Ctenolepisma urbani* for some of our more common types of paper.

Various papers, some of them furnished by a local wholesale paper firm, were cut into 2″ squares and tacked on to strips of wood. 10 sets of these papers were placed beneath the badly infested auditorium and examined at weekly intervals. The amount of feeding was graded according to the arbitrary method indicated below:

A.—Feeding upon a large part of the paper; B.—Feeding upon a small part of the paper; C.—A few nibble marks; E.—No feeding.

The results of this experiment are indicated in table 2.

Table 2.—Paper preferences of *C. urbani* based on the average of 10 sets or each paper tested.

PAPER	RATING OF FEEDING	
	1st week	2nd week
Cleansing tissue (*Kleenex*)	A	A
Hamilton Bond	C	C
Kleerfect Super	C	C
Newsprint (unprinted)	E	E
Newsprint (printed)	E	E
Glazed on one side	C	C
Cellophane	A	A
Cardboard	E	E
Brown wrapping paper	E	E
Slick magazine paper	C	C
Wax	C	B
Toilet tissue	E	C
Washroom	E	C
Onion skin	A	A
Yellow chemical	C	C
Blue Bond	C	C
Coupon	E	C

The preference of the silverfish for paper may be arranged as follows:

Extremely well eaten—Cleansing tissue; Onion skin; Cellophane.
Fairly well eaten—Wax; *Hamilton Bond;* Slick magazine paper; *Kleerfect Super;* Paper glazed on one side; Yellow chemical; Blue Bond.
Poorly eaten—Toilet tissue; Washroom; Coupon.
Not eaten—Newsprint (unprinted); Newsprint (printed); Cardboard; Brown wrapping paper.

According to Lindsay (1940) who worked on the palatability of various wallpapers to *Ctenolepisma longicaudata* Esch. this silverfish fed on the various sizes which were mixed with the pigment and filler, being especially fond of such sizes as starch and dextrin. She also found that papers of pure chemical pulp were more likely to be attacked than those consisting in part of mechanical pulp. Her conclusions are borne out by this experiment, for the papers that are well eaten are all highly refined chemical pulp papers, whereas those that were not fed upon have a high mechanical pulp content. However, even the non-preferred papers may show signs of feeding if exposed for a sufficiently long time.

EXPERIMENT 4.—In this experiment the preferences of *Ctenolepisma urbani* for flour pastes mixed with various insecticides were tested.

Yellow chemical paper was cut into strips $2 \times 4\frac{1}{4}$ inches. A paste consisting of 7 grams insecticide, 93 grams white wheat flour, and 200 cc. distilled water was prepared, and the paste was applied by brush to one half of each strip. These cards were then tacked to strips of wood. Ten sets were placed beneath the badly infested auditorium where they were examined at weekly intervals, and graded by the arbitrary method indicated in Experiment 2. Table 3 indicates the preferences of *C. urbani* for poisoned flour pastes.

Table 3.—Preference of *C. urbani* for poisoned flour pastes based on an average of 10 sets used for each material.

POISONED PASTE[1]	RATING OF FEEDING			
	1st week	2nd week	3rd week	4th week
Sodium fluoride	D	D	D	C
Sodium fluosilicate	D	D	C	C
White arsenic	E	E	D	D
Sodium arsenite	E	E	E	E
Tartar emetic	E	E	E	E
Barium fluosilicate	C	B	B	A
Barium carbonate	C	B	B	A
Flour (check)	C	B	B	A

[1] Sodium fluoride was recommended in silverfish baits by Snipes *et al.* (1936), Seiferle *et al.* (1938); white arsenic by Wakeland *et al.* (1931); Barium fluosilicate by Anon. (1936); Barium carbonate by Richardson *et al.* (1940); Sodium fluosilicate by Reichmuth (1936).

The results indicate that, under natural conditions, *Ctenolepisma urbani* will not feed on flour pastes containing tartar emetic and sodium arsenite; it finds flour

pastes mixed with white arsenic, sodium fluoride, and sodium fluosilicate, repellent; and it apparently does not detect barium fluosilicate or barium carbonate in these pastes. Richardson *et al.* (1940) found that barium fluosilicate in dry baits was repellent for the first 24 hours, but not thereafter. This experiment partially ex- *C. urbani* on cards coated with a flour paste containing white arsenic.

EXPERIMENT 5.—Tests were run to determine the mortality time for *Ctenolepisma urbani* when confined in dusts commonly recommended for the control of silverfish.

The dust under consideration was directed from a *DeVilbiss No. 36* powder blower into a 1 oz. salve jar. The bulb of the powder blower was squeezed 5 times. Twenty-five jars were prepared in the testing of each dust. One silverfish was placed in a jar, and the jars were kept at room temperature, 68 to 72° F. In the tests where the silverfish became paralyzed, it was removed from the salve jar after 15 minutes exposure to the dust, and placed in a clean, dry petri dish. The petri dish was kept at room temperature, and examined daily for mortality counts. Previous tests showed that *C. urbani* in most instances survived for 2 or more weeks in clean and dry glassware even though food and moisture were withheld. The results of the test are indicated in table 4.

Table 4.—Average time for 25 individuals of *C. urbani* to become paralyzed or to die when confined in dusts commonly used in the control of silverfish.

Dust	Average No. Minutes To Become Paralyzed	Paralysis Distribution in Minutes	Aver- No. Days To Die	Mortality Distribution in Days
Sodium fluoride			5.0	1 to 18
Sodium fluosilicate			6.8	4 to 10
Pyrethrum[1]	5.4	3 to 10	3.0	1 to 11
Sodium fluoride and pyrethrum[2]	6.9	3 to 11	1.0	1 to 3
Sodium fluosilicate and pyrethrum	6.4	4 to 8	1.0	1 to 3

[1] All pyrethrum used in the test contained 0.75 per cent pyrethrins.
[2] All mixtures in the experiment consisted by weight of 1 part pyrethrum and 4 parts toxic salt.

When *Ctenolepisma urbani* is confined in dusts of sodium fluoride or sodium fluosilicate, it succumbs on an average in 5 and 6.8 days respectively. These common ingredients of silverfish poisons are therefore slowly toxic. When the insect is confined in a pyrethrum dust of 0.75 per cent pyrethrins, it shows signs of great irritation, often within 30 seconds. The pyrethrum dust adheres to the hairs on the body and around the mouthparts, as well as upon all the appendages. It becomes paralyzed, *e.g.*, incapable of locomotion, in from 3 to 10 minutes. The legs are apparently greatly affected, and soon show a lack of coordination. In some instances the legs become detached from the body. The presence of sodium fluoride or sodium fluosilicate in the pyrethrum mixture does not affect the time for paralysis in any notable way. When the paralyzed silverfish is placed in a clean petri dish, it eventually dies in from 1 to 11 days. Specimens not treated in any way survive for two or more weeks in a glass dish.

EXPERIMENT 6.—Tests were conducted to determine the preference of the silverfish for the more common textiles.

Circles, five-eighths inch in diameter, were punched out with a die from the following undyed materials: Linen, cotton, rayon, lisle, silk, and wool. These 6 textiles were nailed to a strip of wood. Ten such sets were then placed beneath the badly infested auditorium and examined at weekly intervals for a period of 6 weeks.

At the end of the first week indications of feeding were negligible. Thereafter feeding could be detected. The results at the end of 6 weeks showed that the vegetable fibers were fed upon, whereas the animal fibers were practically avoided. Linen was the preferred textile. Rayon, cotton, and lisle were also eaten, but not as readily as the linen. The feeding on silk and wool was negligible. When the silverfish were confined in salve jars with the above textiles, the results were identical with those previously cited.

Under natural conditions the silverfish, *Ctenolepisma urbani* will feed on textiles of vegetable origin, such as linen, rayon, cotton and lisle. Linen is by far the preferred vegetable fiber. The feeding by *C. urbani* on fibers of animal origin, such as silk or wool is practically negligible. Damage by silverfish to textiles may be recognized by the presence of feces, scales, the irregular feeding on the individual fibers of the textile, and in certain instances, especially in the case of linens, by yellowish stains. Where damage to textiles is believed to be due to silverfish, a card coated with flour paste may be placed in the vicinity. Subsequent examination for feeding marks

will reveal whether or not silverfish are present.

EXPERIMENT 7.—This test was run to determine the feasibility of trapping silverfish in rooms by means of trap jars.

A trap was prepared by binding the outside surface of a 1 oz. salve jar clear to the rim with scotch masking tape. A teaspoonful of white wheat flour was placed inside the jar. This trap was predicated on two characteristics of *C. urbani*, its attraction to flour, and its inability to climb on clean glass surfaces (or the inner surface of the jar). One hundred such jars were distributed throughout the basement laboratories of a large building where the silverfish infestation was severe. The trap jars were for the most part placed in the corners of a room where they usually were inconspicuous.

According to Lindsay (1940), *Ctenolepisma longicaudata* Esch. of Australia has a long life cycle, one that may extend from 7 to 8 years. Should the adults lend themselves to trapping, possibilities of control may be envisioned.

After 120 days the jars were collected; only 92 of the original 100 jars were recovered. In 18 of these jars a small species of spider had taken up its abode, and had reduced the flour and silverfish into a mass of white webbing, flour, and insect remains, which could not be counted. In each of the remaining 74 jars an average of 13.6 silverfish were trapped or a total of 1008 silverfish for the 74 jars. The great majority of these were dead. This was due in part to cannibalism, and also to the flour which apparently is slowly deleterious to them, for they succumb more quickly in a jar with flour than in a clean and empty jar. The number of silverfish trapped in an individual jar ranged from 0 to 70. Four jars in one room trapped a total of 167 silverfish.—7-23-41.

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Some Recent Advances in the Chemistry and Physics of Spray Oils and Emulsions[1]

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It seems particularly appropriate that a symposium on oil sprays should be held at this time, for the present period is characterized by the increasing complexity of insecticides. In the case of spray oils this complication results from several changing conditions, among which may be mentioned:

a) the use of pyrethrum in fly sprays has been carried over to plant sprays and a host of new synthetic and plant toxicants has been employed.

b) the addition of mutual solvents to produce true or colloidal solutions of substances too insoluble for direct incorporation in oil.

c) the use of oil to decrease the wetting of lead arsentate; etc., by water, thus increasing deposit.

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d) simultaneous deposit of a solid insecticide and an oil to increase adhesion and persistence.

e) addition of materials to alter the rate of penetration of oil—these may either increase or decrease the penetration.

f) synthesis and trial of countless emulsifying, spreading and wetting agents.

g) use of invert emulsions.

h) use of water modifiers.

Petroleum chemists have been extremely busy and have opened up whole new lines of work, especially with aliphatic hydrocarbons(Frolich 1938).[1] These formerly were considered too inert to enter into reactions except under extreme conditions and, consequently, improvement in such products as gasoline or lubricants depended primarily upon better fractionation by means of solvents or high vacuum distillation. However, the introduction of high pressure equipment and improved catalysts has shown that those "inert" hydrocarbons enter into a multitude of reactions which have resulted in such products as Buna rubber, isooctane for aviation fuel, glycerol and synthetic fats. Partly as a result of this activity a flood of new organic compounds of the most diverse kinds has become available in commercial quantities. Of particular interest are those which are useful as emulsifiers, wetters, or spreaders. The bulk of these materials is used in textile scouring and dyeing, laundering, ore flotation, soldering, electroplating, and other manufacturing or industrial operations, but they are of more than potential importance for insecticidal sprays.

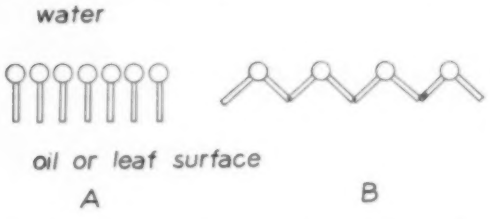

FIG. 1.—Diagrammatic representation of molecular orientation of soap, organic sulphates or sulphonates containing (A) one hydrocarbon chain, (B) two hydrocarbon chains.

EMULSIFIERS AND WETTING AGENTS.—For many years soaps were the standard substances for increasing the wetting power of sprays and for emulsifying oils. These functions can be performed by soaps because all soap molecules consist of two parts, one containing only hydrogen and carbon atoms arranged in the manner of a chain and the other containing hydrogen, carbon, oxygen and a metallic atom such as sodium. The hydrocarbon chain is similar in composition to spray oils or the waxy covering of many leaves, whereas the carboxyl portion is closely akin to water, or other substances containing oxygen. Consequently at the interface between the spray water and an oil droplet or a leaf surface soap molecules will arrange themselves as shown in an idealized manner in figure 1A. The result of this orientation is that the transition from one phase to the other is less abrupt and the tension at the interface is decreased.

The effectiveness of soaps as emulsifiers or wetters is affected by several conditions *e.g.*: 1) if the hydrocarbon chain is short, the whole molecule is soluble in water and but little soap will go to the interface. On the other hand, if it is long the molecule is insoluble in water. Hence only a comparatively narrow range from about 10 to 18 carbon atoms is permissible. This includes such soaps as the laurates (12 C's), myristates (14 C's), palmitates (16 C's), oleates (18 C's) and stearates (18 C's). 2) In the presence of most di- or trivalent salts, such as calcium or iron, insoluble soaps are formed. 3) In acidic water the soaps are decomopsed to insoluble fatty acids.

The fundamental trouble with soaps lies in the carboxyl group, and possibility for improved "soaps" depends upon the use of an acidic group having superior properties. Among the various alternatives are polyvalent acidic groups such as phosphate, borate, sulfate, or any of the polyvalent acid radicals. Among these, sulfate is by far the cheapest and the first artifical "soaps" were made by substituting sulfate for carboxyl as in $CH_3(CH_2)_{11}OSO_3Na$ which is sodium lauryl sulfate, sold under the trade names of *Dreft* and *Ina181*. The *Tergitols* are the sodium salts of higher carbon alcohol sulfates and turkey red oil (miscalled sulfonated castor oil) is the ammonium salt of ricinoleic sulfuric acid ester. All such compounds are esters of the appropriate alcohol, though they are often made by other processes. These are free from some of the objections to soaps; *e.g.*, their compounds with heavy metals

are relatively soluble and they are but little affected by acid waters since the organic sulfuric acid which might be liberated is strong and soluble. However, hot acidic solutions of the alcoholic sulfates decompose readily and lose their soap-like action.

Since fatty acids occur in nature (*e.g.*, in all animal and vegetable fats) and are much cheaper than the corresponding alcohols many attempts have been made to modify the objectionable carboxyl group. A simple way is to form an ester with a cheap sulfated alcohol. For instance, lauric acid and sulfated ethyl alcohol gives a sulfated fatty acid ester. Another method is to react the fatty acid with a sulfated amide to give a sulfated fatty acid amide. Representatives of both these types are on the market but are not of much use in agriculture.

The simplest reaction of sulfuric acid with an organic molecule results in the formation of organic sulfates as just described but another reaction is possible whereby the *sulfonates* are formed; *e.g.*, $CH_3(CH_2)_nCH_3 + HO\overset{O}{\overset{\|}{S}}OH$ (hot and concentrated) $\rightarrow H_2O + CH_3(CH_2)_nCH_2\overset{O}{\overset{\|}{S}}OH$. In this case the carbon and sulfur are connected directly instead of through an oxygen atom as in the sulfates. For this process the very cheap hydrocarbons may be used. An example is *Ultrawet*. Since the sulfonation takes place especially well with aromatic hydrocarbons several products formed from benzene, naphthalene, etc., are available, such as *Santomerse*, *Areskap*, and *Aresket*. The ester and amide derivatives of fatty acids reacted with sulfonates are also represented; *e.g.*, by *Igepon A* (oleic acid+sodium salt of hydroxyethane sulfonic acid) and *Igepon T* (oleic acid+sodium salt of aminoethane sulfonic acid). While *Igepon A* is not stable in alkali because it splits at the ester group and forms ordinary sodium oleate, *Igepon T* is stable in both alkaline and acid conditions.

All these varieties of compounds behave like soap at an interface; *i.e.*, the hydrocarbon (or nonpolar) end is directed to the oil or wax while the polar sulfate or sulfonate part is in the water. Hence figure 1A may be considered to represent them also. However, it must be remembered that the degree to which an orderly, closely compact layer of oriented molecules may be formed at an interface is dependent upon the concentration, solubility, length of the hydrocarbon chain and relative polarity of the carboxyl, sulfate or sulfonate group. Differences among various compounds with respect to these properties account for the great gradation in their effectiveness.

Instead of using a monocarboxylic acid (as oleic), products of a different nature may be made by reacting dibasic acids with sulfonated compounds. For example, *Aerosol OT* and a series of related compounds are sulfonated derivates of succinic acid, COOH CH_2CH_2 COOH. *Aerosol OT* was used in the experiment that resulted in a duck nearly drowning (Howe 1941). The reason was that the wetting power of the *Aerosol* solution (only 1 part to 2500 of water) was so great that it penetrated all through the duck's feathers and destroyed their buoyancy. These compounds with two hydrocarbon groups behave differently from the typical soap-like materials as shown diagrammatically in figure 1B. The area covered per molecule is much greater than in the case of figure 1A and hence these substances should be and are effective wetters at very low concentrations. Small changes in the molecular configuration lead to marked alteration in the wetting power and as yet no generalizations can be made (Caryl 1941). It is to be noted in figure 1B that in place of carboxyl, sulfate or sulfonate groups a ketone, thioketone, alcohol, amine or ammonium radical may be used. Such compounds are, in general, not very effective emulsifying or wetting agents but certain of them are very useful for special purposes.

The foregoing discussion has no more than suggested the multiplicity of synthetic compounds now available and of possible use in sprays. The question may be asked why such a variety of wetting agents should ever be made. The answer lies partly in the fact that each large company making products that require such an agent desires to have full control of its manufacture and use, and partly in the more important fact that each modification in the molecule not only changes the conditions of acidity, etc., for use, but usually changes the suitability for a particular use. Thus a wetting agent well adapted to aid in floating a particular ore

or for dyeing linen may be totally unfitted for use in an oil spray. In fact, every variation in the composition of the spray as well as in the nature of the sprayed surface calls for a consideration of the proper wetting agent. There has been and still is a tendency on the part of manufacturers and of insecticide salesmen to suggest that because a wetting agent is good for some particular use it is automatically

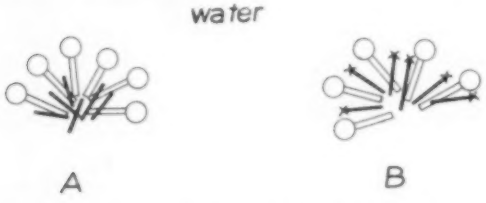

FIG. 2.—Colloidal aggregates such as soap or organic sulphonate containing (A) non-polar hydrocarbon, (B) semipolar compound such as a higher alcohol.

good in a spray. As a matter of fact, high wetting power is often undesirable in a spray for deposit is then low (Hoskins & Ben-Amotz 1938).

Since most of the synthetic compounds mentioned allow only low deposits of oil they are of limited use with insecticidal oil sprays. One significant advance, however, particularly from the manufacturers' viewpoint, has been the use of oil-soluble emulsifying agents. These are dissolved in the spray oil and the solution need only be added to the proper amount of water to obtain a finished spray. This avoids the necessity for preparing concentrated emulsions which often do not keep well. Also it is handier for the user than the tank-mix method. Many of the sulfonated petroleum compounds are readily soluble in oil and certain of them are used in various commercial emulsive oils.

SOLUBILIZERS.—Other speakers on this symposium will discuss at length the use of toxic substances dissolved in oil, but there are certain chemical points which merit attention at this moment. Ordinarily, petroleum oils are considered as insoluble in water or in aqueous solutions and dispersions of one in the other are spoken of as emulsions. However, it was shown by Pickering (Pickering 1917) that oil is soluble in 16 per cent potassium stearate solution to the extent of 1.3 per cent, and in the case of benzene the solubility is much higher. This condition is radically different from dispersion of the oil in fine droplets, for in the latter condition the system is more or less unstable and the vapor pressure of the oil is greater than it is in the bulk condition. It has been shown (McBain & O'Connor 1940) that the hydrocarbon hexane, C_6H_{14}, is soluble in 0.18 molal potassium oleate solution to the extent of 1.3 per cent by weight and that in all concentrations up to saturation the vapor pressure is substantially less than that of free hexane.

The mechanism of the solubilizing action is somewhat in dispute (Smith 1932; Hartley 1937; Lawrence 1937; McBain *et al.* 1941) but it is clear that those substances which at very low concentration (1 per cent or less) are able to markedly increase the solubility of an otherwise insoluble material are all of an amphipathic nature; *i.e.*, one portion of the molecule is polar and the other nonpolar. When added to water, such substances, e.g., soap or any of the detergents and wetting agents previously mentioned, exist in large part as micelles or colloidal aggregates (*cf.* Fig. 2A). The micelles in water have the polar radicals outward and the center consists largely of hydrocarbon chains. It is reasonable to expect that a hydrocarbon such as a petroleum oil might dissolve in the interior of the aggregate as indicated by the solid lines in figure 2A. If, instead of a hydrocarbon, a compound with a somewhat polar group is considered, such as a higher alcohol or a thiocyanate, this polar group may be expected to enter into the surface of the micelle, giving the condition shown in Figure 2B, in which the cross represents an alcoholic, thiocyanate or similar group.

It will be obvious that the foregoing discussion bears on the problem of preparing aqueous sprays containing an insoluble insecticide, but for the present purpose it is particularly interesting to note that the same solubilizing action may occur in nonaqueous solvents. Thus, McBain, *et al.* 1940, found a number of dyes which are not appreciably soluble in heptane, benzene or toluene, but which dissolve to varying degrees in the presence of 1 per cent of such compounds as diglycol laurate, *Aerosol OT* (sodium sulfonate of dioctyl succinic ester), *Aerosol OS* (sodium alkyl naphthalene sulfonate), sodium resinate and numerous other similar compounds. They venture the prediction that it is possible to solubilize almost any

material in any solvent. Undoubtedly the use of ketones, phthalates and *Cardolite 627* to promote the solution of rotenone in oil depends to some extent upon the formation of colloidal aggregates of the solute and the solubilizer. In this case the formation probably is the reverse of that shown in figures 2A and B; *i.e.*, the nonpolar groups will be on the outside next to the oil and the polar groups in the interior of the aggregates. A solute held in solution in oil by this mechanism is less likely to pass into the aqueous phase than if it were dissolved in the ordinary way. This may be of value in connection with derivatives of nicotine which tend to escape from solution in oil (Norton 1940, 1941). It may be worth while to suggest that the chemists and entomologists who are interested in toxic solutions should pay heed to the work on solubilizers effective at very low concentrations, and especially to the experiments of Prof. McBain at Stanford University.

PENETRATION OF SPRAY OILS.—Attention is being directed to small amounts of solute in spray oils for the additional reason that movement of the oil upon surfaces and penetration into plants and insects are thereby altered. A conspicuous example is the group of larvicidal oils used in various parts of the world to kill mosquito larvae. A very careful study of these oils has recently been made by Murray (1936, 1938, 1939) in England. An essential for good spreading and persistence of the film is the presence of a small amount of amphipathic substances. Their chemical nature is largely unknown but they are formed during cracking of petroleum and by irradiation of the oil. Polymerized unsaturated hydrocarbons and certain petroleum sulfonates promote spreading but straight chain fatty acids and alcohols tend to retard spreading. All spreaders of this type are removed by fuller's earth.

It has been known for several years that the addition of glyceryl oleate and similar compounds slows down the penetration of oil into citrus leaves. This situation has recently been re-examined by Ebeling (1939), who found four compounds at 1 per cent concentration in grade 4 spray oil to be effective in retarding penetration of the oil in the following order: triethanolamine oleate > glyceryl monooleate > glycol monooleate > glyceryl oleate. Since the effect of these compounds is most marked when the stomata are closed it follows that they play a part in the penetration through the leaf cuticle; *i.e.*, in true membrane penetration. If one follows the pore theory of membranes the action of these compounds could be explained by assuming them to become fixed on the walls of the pores, thus more or less obliterating the available passageways. On the solution theory, they may be assumed to form a tight union with the components of the membrane which would otherwise dissolve and pass along the oil molecules. In either case the variation in efficiency correlates with the three, two, one and no hydroxyl groups which the respective compounds contain.

In contrast to these results with leaves some recent work (Hurst 1940, 1941; Wigglesworth 1941) on penetration of insect cuticle is of special interest. The contact toxic action toward the bedbug of various unsaturated components of naphtha was found to be greatly enhanced in the presence of nonpolar paraffins. That the effect was due to increased penetration of the toxic substances is indicated by an experiment with larvae of the blowfly, *Calliphora erythrocephala*. When this organism is placed in ethyl alcohol it remains active for at least an hour and similarly in refined kerosene it is affected even more slowly. But if placed in a solution of the alcohol in kerosene, the larva swells at once and bursts within a few minutes. During the swelling water passes outward through the integument. Evidently, ethyl alcohol is able to pass but slowly through the integument; kerosene passes readily but is not very toxic and when both are present together the penetrating kerosene carries in the alcohol which displaces part of the body water. It is likely that many instances in which a given toxicant is more effective in the presence of oil are capable of an analogous explanation. A non-biological situation somewhat similar to that just mentioned has been noted by McBain (McBain & Woo 1937). He placed a dilute solution of lauric acid or similar compound in *Nujol* upon water or dilute alkaline solution and found the diffusing fatty acid or soap to carry along considerable oil into true solution in the aqueous layer.

OXIDATION OF SPRAY OILS.—The discovery of the unsulfonatable residue test by Gray & deOng in 1915 and its an-

nouncement in 1926 (Gray & deOng 1926) may be said to mark the beginning of the present era of oil sprays, for by this test it was possible for the first time to predict how an oil would affect a plant. With remarkable little skepticism both the oil industry and agriculture accepted the criterion; in fact, it was accepted too complacently, and not for several years were its limitations first critically examined. In 1936 Tucker (1936) pointed out that the hydrocarbons of spray oils have little toxic action toward leaves until they are oxidized to oil-soluble acids. Saturated oils are oxidized too slowly to become harmful under ordinary conditions of use and slow oxidation is also characteristic of unsaturated hydrocarbons if kept in the dark. Upon exposure to sunlight, however, the latter rapidly absorb oxygen and become increasingly dangerous. Hence, whenever oil is applied to leaves and tender twigs a shifting balance is set up between loss of oil and conversion to toxic forms and, depending upon circumstances, safety or injury will result. Release of reactive oxygen as a result of metabolic processes in the plant may give further opportunity for oxidation of oil. It will be obvious that many uses to which oils are put offer opportunity for oxidation; *e.g.*, in engines and motors, in transformers, and in insulated cables. Some of the best recent work on oxidation of oil has come from problems arising in these uses.

A distinction may be made between oils composed primarily of aromatic hydrocarbons and those chiefly paraffinic in nature, for the former absorb oxygen and develop acidity at a more or less uniform rate whenever exposed to light and oxygen, whereas with the latter these processes are delayed during a latent period. Following this slow start the processes proceed at an accelerating rate until greater changes may occur with paraffin than with aromatic oils (Fenske *et al.* 1941a.). This induction period may be long enough for much of the oil to disappear from the leaf surface and the greater tolerance of plants toward paraffin oils is partly due to it. Of course, any success attained in holding a spray oil on the surface of leaves gives greater opportunity for the development of the dangerous acidic derivatives.

Unfortunately, a very great amount of work has not yet revealed all of the factors entering into the development of acidity in petroleum oils, but it is known that the presence of compounds with double bonds is a sure sign of reactivity, especially if two double bonds are present in the conjugated position, as —CH=CH —CH=CH—. The first reaction with oxygen is the formation of peroxides and acids appear somewhat later. Their nature is largely unknown, and one of the outstanding problems still at hand is their precise identification. One estimate of the empirical composition is that there is one carboxyl group in a molecule of molecular weight about 1500 (Fenske *et al.* 1941b.). The ultraviolet component of sunlight (wave length less than 300 mμ) is the most effective portion and, as might be expected, x-rays and β-rays also are able to bring about oxidation of oils in the presence of air (Stenstrom & Vigness 1938). Obviously, development of acidity in an oil will be especially undesirable when the oil contains a toxicant which is sensitive to such acids.

It was observed many years ago that very highly refined petroeum oils may develop more acidity than less refined preparations exposed in an identical manner This fact was explained on the basis that natural inhibitors occur in oils and persist through the ordinary refining process until extreme treatment with strong acid and filtering clays. Their nature is still in doubt but a host of synthetic substances have been patented for this purpose (Fenske *et al.* 1941). Most of these are phenolic derivatives, amines, sulfur compounds such as disulfides, thioethers or thioureas, or halogen derivatives. While many such substances are finding extensive use with oils for industrial purposes, they are not commonly employed in sprays. The usual degree of refinement of spray oils is such that they retain a large part of their natural complement of inhibitors.

The foregoing remarks indicate that the solubility of a petroleum oil in strong sulfuric acid is to a considerable extent only a fortuitous indication of its tendency to oxidize. The extreme example is given by synthetic oils formed from unsaturated hydrocarbons by a polymerization process. These are completely soluble in hot, concentrated sulfuric acid (UR=O) and yet they are relatively harmless to plants in reasonable amounts. A very large number of chemical tests have been suggested,

such as absorption of oxygen, production of volatile acids, or of carbon dioxide, absorption of iodine, solubility in dimethyl sulfate, etc.; but up to the present none of these has displaced the unsulfonatable residue test. If any decided change in the source or method of manufacturing of spray oils should take place a new criterion of safety probably will be required.

The use of other insecticides with spray oils might be suspected of favoring oxidation of the oil in some cases. An interesting study of oil plus sulfur, hydrogen sulfide, organic sulfides, organic mercaptans and organic disulfides showed[1] that none of them affected oxidation of the oil either in sunlight or darkness but that leaf injury resulted from addition of the sulfur in any of these forms. This effect was particularly marked with free sulfur or the disulfide. It is, of course, commonly known that the oil-sulfur combination is often dangerous to foliage.

In conclusion, the main points of this discussion may be very briefly summarized under four heads:

1) An increasing flood of synthetic wetting and emulsifying agents is available but most of them are of doubtful value in oil sprays because they reduce deposit.

2) Under the influence of solubilizing agents, oil becomes soluble to a marked extent in aqueous solutions and the same phenomenon occurs with "insoluble" substances in oil as a solvent in the presence of the proper solubilizer.

3) The spreading of oil upon water is promoted and penetration into foliage is retarded by small concentrations of semipolar compounds. On the other hand, inert hydrocarbons such as oils seem to assist semipolar toxic compounds, for instance alcohols, in penetrating insect integument.

4) Lastly, oxidation of unsaturated hydrocarbons to form complex acids is chiefly responsible for leaf injury. The unsulfonatable residue test is not always a satisfactory criterion for estimating the tendency to oxidize but a practical substitute test is yet to be found.—9-2-41.

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Methods of Measuring Spray Oil Deposits

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The final criteria of the efficiency of oil sprays are insect kill, host-plant reactions, and cost, but the variation in the quantity of oil deposited by sprays of equal oil content may make results difficult to interpret and retard the progress of fundamental lines of investigations. For example, in studies of the relation between insect mortality and physical or chemical properties of oils, differences in effectiveness may be due to correlations between oil characteristics and the quantity of oil deposited as well as between oil characteristics and toxicity. When toxicants are combined with oils, an increase in effectiveness may be due to greater oil deposits as well as to the toxicity of the added material, or toxic action may be obscured by decreased oil deposits. Such considerations illustrate the desirability of measuring oil deposits.

De Ong *et al.* (1927) showed that the oil deposited by casein-lime emulsions depended on the emulsifier content. Aside from insect kill, they used the percentage of oil in the run-off from a glass surface as compared with the oil content of the spray as an index of oil deposited. Griffin *et al.* (1927) showed that insecticidal effectiveness was correlated with the droplet size of emulsions, and used the oil content of the run-off from sprayed plants as an indication of the oil deposits. They stated that their results were estimates only of the quantity of the oil retained by the plants.

The first method for directly measuring oil deposits on the foliage was described by English (1930). Disks cut from sprayed leaves were extracted with two successive portions of ethyl ether, the solvent was evaporated, and the oil plus leaf extract recovered by centrifuging in skim-milk test bottles. Unsprayed leaves were extracted to determine the amount of leaf waxes and oils removed. The extraction method used by English has been criticized on the ground that the oil is not completely removed thereby, but few quantitative data as to the error involved have been published. Rohrbaugh (1934) stated that oil could be recovered from ground tissue of citrus leaves that had been shaken with ether for 30 minutes before grinding. Dawsey & Hiley (1937) extracted disks from chrysanthemum leaves with four portions of ethyl ether and then dried, ground, and reextracted the same samples. They found that 91.8 per cent of the oil recovered was contained in the first extract. The leaves stood 2 or 3 days after spraying before extractions were made, and disks were of 1.0 cm. diameter as compared with the 3.6 cm. diameter used by English. It is to be expected that extraction efficiency will vary inversely with the size of the disk and the interval between spraying and extraction.

Swain & Green (1933) washed the surfaces of sprayed leaves with methylene chloride, evaporated the solvent at 45° C., dried for 2 hours at 45 to 50°, and weighed. The method was developed primarily for measuring surface oil, but the authors state that it can be used for measurement of total deposits provided the leaves are washed before any appreciable penetration of oil into the plant tissues has occurred. Dawsey (1936) pointed out that

since petroleum oil and leaf-surface wax are mutually soluble, uncertainty exists as to what percentage of surface oil can be removed each time by a single methylene chloride washing.

Dawsey & Haas (1933) proposed a modification of the English method designed to minimize errors resulting from the variable amount of leaf waxes and oils that they encountered. After extraction of disks with ethyl ether, the solvent was evaporated and the residue dissolved in a mixture of ether and absolute alcohol. This was cooled until the leaf waxes precipitated and was then filtered at −6 to −20° C., the temperature depending on the kind of leaves used. The filtrate was transferred to skim-milk test bottles, the ether evaporated, and the residue treated with concentrated nitric acid to destroy the unsaturated compounds and chlorophyl. The bottles were then filled with acid and centrifuged. This method was designed for a highly refined oil, but Dawsey (1936) has extended it to the less refined oils and suggested omission of the wax-freezing step. Nitration curves were determined to correct for losses of the less refined oils. The extraction method is similar to the English method and open to the same criticism. Disadvantages of the leaf-wax-separation step are that the optimum temperatures for freezing the waxes differ for various plants and that many spray oils will not pass through the filter at these temperatures.

Because the percentage recovery of oil by the English method of extraction is uncertain and may vary with such factors as size of disks, time between spraying and extraction, and type of foliage, it is desirable to have a method that will completely remove the oil. Rohrbaugh (1934) dried and ground citrus leaves and then extracted a weighed amount of the ground tissues by soaking in petroleum ether for 30 minutes with shaking every 5 minutes. The solvent was then evaporated and the residues sulfonated, after which they were transferred to milk test bottles and centrifuged to recover the oil. In this way the oil was separated from the large amount of waxes extracted from the ground leaves. This method was developed in connection with an investigation on the penetration and accumulation of oils in the tissues of citrus trees, and Rohrbaugh stated that the volatile portion of the oils probably disappeared during the drying of test samples but that such loss was probably small when samples were collected more than 10 days after spray application. Later work, by the writer, on the rate of oil loss from sprayed leaves suggests that estimates of initial deposits of certain oils by this method may be considerably low. Reference of the oil recovered to the mass of the sample seems undesirable in insecticidal studies, but it could be expressed in terms of oil per unit area by determining the area of the sample before grinding, as described by Quayle (1938). Measurement of the less-refined oils would require sulfonation curves. This extraction method has proved useful in checking completeness of removal of oil by other methods.

Dawsey & Hiley (1937) proposed a method of extraction which overcame some of the above difficulties. Leaf disks of 1 cm. diameter were cut from sprayed chrysanthemum leaves and extracted with petroleum ether in the A. S. T. M. rubber-extraction apparatus. This was later changed to the Bailey-Walker apparatus, which permitted the simultaneous extraction and filtration of seven samples. After continuous refluxing for 2 hours in weighed flasks, the solvent was evaporated, the flasks dried to constant weight, and the residue weighed. Drying, grinding, and re-extracting disks that had been treated in this way showed no further recoveries of oil provided the first extractions were made with freshly cut disks. This method was used successfully on apple and willow foliage as well as chrysanthemum, and it has been used at the Whittier laboratory of the Bureau of Entolmology and Plant Quarantine, United States Department of Agriculture, in measuring deposits on citrus foliage. Dawsey & Hiley first dried their residues for 2 hours at 110° C., but found that an appreciable portion of a petroleum oil was lost in this way, the loss ranging from about 20 per cent of a 30-mg. sample of oil to 7 per cent of a 100-mg. sample. The same oil, which was somewhat less volatile than oils used on citrus, could be dried in a vacuum dessicator at room temperature and a pressure of 2 to 3 mm. of mercury without loss. An alternative drying method has been adopted at the Whittier laboratory and will be described later. One advantage of this method of analysis is the time saved. The extraction time can be automatically con-

trolled by a time switch and one's time during this operation and most of the drying period is free for other work. Another advantage lies in the fact that there is no transferring of a solution in a volatile solvent, the residues being weighed in the same flasks in which they are extracted. The method is applicable to glyceride as well as petroleum oils. A possible disadvantage is the limited sample size, which is restricted by the capacity of the filter thimbles. Dawsey used 200 disks of 1 cm. diameter from chrysanthemum leaves and the writer has found 100 disks of 1.5 cm. diameter from lemon leaves to be the maximum that can be handled in one thimble.

Tihenko & Hensill (1937) washed sprayed leaves with acetone. The acetone and water were evaporated and the residues taken up with petroleum ether and transferred to babcock bottles, where they were sulfonated after evaporation of the ether. The oil was then separated by centrifuging. Hensill (1940) later made a number of changes in the details of this procedure and applied the revised method to field sprays. Leaves were cut about 10 minuted after spraying and washed with acetone in the field. The washings were then transferred to 1-liter erlenmeyer flasks and brought to the laboratory. The acetone was distilled off in a water bath at 70° C. and the residue transferred to a 250-cc. flask, the liter flask being rinsed several times with about 25 cc. of petroleum ether. The petroleum ether was distilled and recovered. The residues were then transferred to sulfonation bottles with petroleum ether, which was then evaporated, after which the sample was sulfonated and finally centrifuged at 60 to 65° C. Tihenko & Hensill recovered 97 per cent of a known amount of oil that had been smeared on orange leaves, and Hensill has obtained good agreement between duplicate samples in both field and laboratory tests on citrus. Hensill has also measured deposits on wood, using young growth ("the year's sucker growth") of Kelsey plums. The necessity for washing the leaves directly after collection in the field may be a disadvantage under some conditions. Ebeling (1940*a*) has pointed out that acetone is a less efficient solvent than some of the less polar compounds.

Ebeling (1940*a*) has described a method of measuring oil deposited by laboratory sprays in which penetration is greatly reduced by limiting the spray to the upper surface of the leaves. The leaves were fastened against a steel plate with the upper surface exposed to the spray. After spraying, they were kept in a cool, dark basement for 2 to 4 hours until the water had dried. The oil was then removed by washing with petroleum ether, the ether evaporated, and the residue weighed. The method of removing the oil was modified in a later article (Ebeling 1940*b*). After the leaves were dried, the oil on the upper surface was absorbed onto filter paper by pressing in a vise. Oil was removed from the filter paper by extraction for 1 hour with petroleum ether in the A. S. T. M. rubber-extraction apparatus, equipment which had been used by Dawsey & Hiley (1937) for extracting leaf disks. The ether was partially evaporated on a hot plate, the residues were transferred to 50-cc. beakers, and evaporation was completed with an air stream while the beakers were immersed in tap water. Residues were then weighed. Ten tests in which 300 to 400 mg. of oil were smeared on 40 orange leaves and recovered by this method showed a small range of error (from 1.9 to −2.6 per cent).

The methods used at the Whittier laboratory are based on those described by Dawsey & Hiley (1937), the oil being extracted by refluxing disks from sprayed leaves for 2 hours with petroleum ether. The principal modifications have been in the methods of holding samples and the final drying of the residues.

Rohrbaugh (1934), Hensill (1940), and Ebeling (1940*a*, *b*) appear to have been concerned primarily with the effect of oil penetration into the leaf tissues upon extraction of the oil. Less attention has been paid to the rate of oil loss from the foliage by evaporation, or possibly other means, during short intervals after spraying. The rate at which recoverable oil disappeared from lemon foliage sprayed with 1 per cent of light medium oil in October 1939 is as follows:

Leaves sprayed at 10:30 A.M. and initial sample taken at 12:30 P.M.

	Oil lost, per cent
Oct. 19, 2:15 P.M.	17
19, 5:30 P.M.	29
20, 8:30 A.M.	28
21, 8:30 A.M.	42

Leaves sprayed at 3:30 P.M. and initial sample taken at 5:30 P.M.

Oct. 20, 8:30 A.M.	3
20, 1:45 P.M.	9
21, 8:30 A.M.	20

With the first spraying about 29 per cent of the oil was lost between 12:30 and 5:30 P.M. There was no measurable loss overnight, but after 8:30 A.M. the loss continued at a slower rate. Following the second spraying there was no significant loss between 5:30 P.M. and 8:30 the next morning. After this the loss of oil was somewhat slower than the initial rate observed for the first spraying. This slower rate of loss may have been due to penetration of oil overnight, since this would give less surface oil the following morning. A number of tests with light medium to heavy medium oils have given consistent results in that they showed a relatively rapid loss of oil during the daylight hours following drying of the spray but little or no loss at night. It is possible that the leaves act as distillation plants, the large quantities of water vapor and other gases given off by the leaves causing rapid volatilization of oil from the thin film present on the leaves. Whereas the writer's results have been consistent with respect to the diurnal changes in the rate of loss, there has been considerable variation in the quantities lost when the kind of oil or time and place of application differed. As an example of extreme difference, the oil applied on October 19 showed 42 per cent loss in 2 days and another brand of light medium oil applied November 13 showed only 14 per cent loss in 3 days.

If samples are extracted within 10 minutes after application, as proposed by Hensill, this variable rate of loss should have little chance to affect the accuracy of the oil-deposit measurements. However, the method of extraction used at the Whittier laboratory is not suitable for field use. Moreover, extraction in the field makes it difficult to supervise spray applications, something that is usually necessary in experimental work. There are advantages, therefore, in a method of holding samples that does not require immediate extraction of the oil.

In the method finally adopted, the leaves were collected as soon as spray drip had ceased and put into 1-pound cans which were closed and kept in a field icebox held near or below 32° F. When brought to the laboratory the cans were stored in a refrigerator at 26 to 28° until disks were cut and extracted. The results of experiments designed to test the reproducibility of results by this method are given in table 1.

Table 1.—Recovery of light medium oil from samples held in refrigerator and from field samples. Average initial deposit 27.2 mg. and analyses made in triplicate.

TIME BETWEEN SPRAYING AND ANALYSIS, DAYS	CHANGE IN OIL RECOVERY, PER CENT	
	In Refrigerator	In Field
1	+0.8	−20
3	+0.4	−31
5	+0.8	−39

There was no loss of oil in the samples held in this way over a 5-day period, the recorded changes being well within the sampling error. This procedure has been checked in a number of field applications covering the range of light medium to heavy oils, and the average losses over a 2- or 3-day interval have ranged from zero to 3 per cent. An error of 3 per cent in the estimation of field spray deposits is of no practical importance. Exposure to higher temperatures than those specified has resulted in measurable losses.

The other principal change has been in the manner in which the residues are finally dried. The procedure is as follows: After the extraction has been completed, the petroleum ether is partially evaporated on a hot plate, after which the evaporation of the solvent is completed at room temperature by directing a jet of air into each flask. The flasks are then placed in a specially constructed rack, as shown in figure 1, and dried for 1 hour at 55° C., while a slow air stream is directed in each flask. One and a half to 2 hours are allowed for the flasks to come to equilibrium with room conditions before they are weighed. An empty flask is included with each set of samples in order to check any changes in weight due to changes in temperature or humidity of the room. Tests with known amounts of oil showed no measurable loss of a heavy oil and about 6 per cent loss of a light medium. Corrections are always made for loss of light medium and medium oils.

Removal of oil by extraction of the disks was checked by drying the pre-

viously extracted disks, grinding them to a fine powder, and reextracting this powder. Extracts were then transferred to skim-milk bottles, the solvent evaporated, and the residue sulfonated and centri-

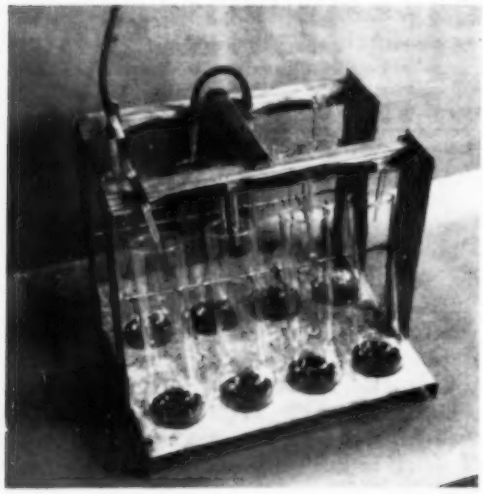

FIG. 1.—Drying-rack with extraction flasks.

fuged. (The large amount of natural oils and waxes recovered from the powdered leaves makes sulfonation necessary.) The amount of oil recovered from fresh or refrigerated leaves by the second extraction ranged from zero to 2 per cent of the total deposit. In one case leaves were taken from trees 13 days after spraying and extracted in the usual way. Disks were then powdered and reextracted, and one sample showed no oil and the other a trace. In so far as this method of reextraction is a valid test of the removal of the oil, therefore, it appears that any oil remaining after 2 hours' extraction of fresh disks was insufficient to interfere with the estimates of relative deposits. When the leaves were allowed to dry before extraction of the disks, however, removal of the oil was less satisfactory.

McCall & Kagy (1940) have described a colorimetric method for measuring deposits in laboratory sprays. An oil-soluble dye, sudan III, was dissolved in oil at the rate of 0.025 g. per 100 cc. Leaves were then sprayed in the laboratory and the oil was removed from the upper surfaces by atomizing a small quantity of kerosene over the leaves. Comparisons with standards were then made in 50-cc. nessler tubes. Recovery of known amounts of oil smeared on orange leaves averaged 98.4 per cent.

These writers state that the method can be adapted to certain types of field experiments. However, its efficiency under field conditions, where removal of oil from both surfaces is involved, has not been checked. It would also be desirable to check the effect of the added dye upon the deposits produced by sprays. The present writer found that the interfacial tension between water and a kerosene was lowered from 46 to 25 d. per cm. by the addition of sudan III to the kerosene.

For the various experiments mentioned the quantity of leaf material per sample has differed, in the size and number of disks and in the number of whole leaves. In the earlier methods described by English (1930) and by Dawsey & Haas (1933) extractions were made from disks of known area cut from leaves. After Rohrbaugh (1934) pointed out that oils were not distributed evenly over the leaves there has been an increasing tendency to use whole leaves. However, there appear to be no quantitative data published on the comparative results with whole leaves and disks. At the Whittier laboratory four disks of 1.5 cm. diameter cut from each of 25 leaves have been adopted as the standard sample. The disk areas are located as is shown in figure 2. Usually it is the relative rather than the absolute oil deposits that are of interest, and the disk method of sampling should be adequate for this purpose provided care is taken to cut the disks at the same locations on the leaves

FIG. 2.—Leaves with disks removed for oil-deposit analysis.

each time. The number of leaves per sample has generally ranged from 25 to 50 distributed over several trees, although Rohrbaugh used 500 or more. Care must be taken to obtain leaves of uniform age and type of surface. Data by Allison (1931), Rohrbaugh (1934), and Hensill (1940) on deposits on citrus trees show agreement of replicate samples within 10 per cent or less, but Cressman & Dawsey (1934, 1936) found larger variations on camphor foliage.

Ethyl ether, petroleum ether, methylene chloride, and acetone have been used as solvents which can be evaporated without appreciable loss of oil. Rohrbaugh (1934), Dawsey & Hiley (1937), and McCall & Kagy (1940) have reported that petroleum ether removed less material from unsprayed leaves than a number of other solvents. If large quantities of petroleum ether are used in the extraction, the nonvolatile residue may be appreciable and should be determined.

It is difficult to make any direct comparison of the efficiency of different methods from the published data on oil deposits, since differences in emulsions, methods of application and plants sprayed are involved. The most recent data on deposits on citrus are those published by Hensill (1940). Deposits on Valencia range from 1.67 per cent of emulsive oil ranged from 64 to 82 micrograms per square centimeter, and from 2 per cent of emulsive oils on lemons, from 59 to 113 micrograms. In work at the Whittier laboratory a number of applications of 1.67 per cent of an emulsive oil on lemons have produced deposits arranging from 90 to 107 and sprays of 2 per cent emulsive oil from 110 to 115 micrograms per square centimeter. While these tend to average somewhat higher than those reported by Hensill, the differences are not too large to be accounted for by differences in the oils, application, or the host trees.

Numerous investigators have studied spray deposits on artificial surfaces, especially glass and wax. However, Dawsey *et al.* (1937) showed that deposits on plants could not be estimated from plate deposits when different emulsifiers were used. They measured oil deposits on paraffin-covered plates and chrysanthemum leaves, using several emulsifiers and a range of oil concentrations. The same oil was used in all tests, and conditions of application were carefully controlled. Nevertheless, the ratios of the deposits on the two surfaces varied with different emulsifiers, and the ratio changed with the oil and emulsifier concentration when certain soaps were used.

Similar objections may apply to any attempt to standardize field sprays on the basis of laboratory behavior. Ebeling (1940*a*) measured the deposits resulting from spraying the upper surface of citrus leaves in the laboratory with an oil-toxicant spray with and without walnut-shell flour. In one test the addition of the walnut-shell flour caused an increase of about 25 per cent in the oil deposit, but in another test, with greater velocity and volume of spray, walnut-shell flour had practically no effect on deposits. In another series of tests the decrease in deposits produced by adding blood albumin spreader to a spray oil ranged from about 6 to 56 per cent when the spraying conditions, especially the volume of spray and form of spray stream, varied from day to day (Ebeling 1940*b*).

A great deal of fundamental information about the behavior of sprays is being obtained from work with standard surfaces. However, the evidence obtained indicates that even relative deposits from field sprays cannot be inferred directly from laboratory tests because of the difficulty in duplicating field conditions.

SUMMARY.—Various methods of measuring deposits of spray oils are reviewed.

All methods except one colorimetric analysis involve extraction of the oil from the sprayed surface with a suitable solvent, evaporation of the solvent, and either volumetric or gravimetric measurement of the extracted oil.

Both whole leaves and disks of known area have been used. Although the distribution of oil may not be uniform over the whole leaf, the disk method of sampling is considered adequate for measurement of relative results. Rapid loss of oil following application of field sprays necessitates either prompt extraction or storage of samples at low temperatures.

It is doubtful whether relative deposits in field sprays can be inferred directly from laboratory measurements, since differences in the surfaces or conditions of application may change the relative quantities of oil deposited by different sprays.
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Solubilizers for Petroleum Oils and Extracts of Rotenone-Bearing Roots[1]

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Solutions of petroleum oils and extracts of rotenone-bearing roots have been in use for many years for the control of certain species of insects. In 1929 certain proprietary mixtures that consisted mainly of petroleum oil and extracts of rotenone-bearing roots were available. R. H. Smith (1929), in studies with toxicants in oil for the control of the California red scale, *Aonidiella aurantii* (Mask.), pointed to the necessity of a mutual solvent or solubilizer to effect solutions of the extracts in petroleum oil. Smith suggested such solvents as iso-propanol, n-butanol, oleic acid, pine oil, and dibutylphthalate.[4]

O'Kane[5] (1930) patented an oil solution of an extract of derris in a highly refined oil. Since this date numerous chemicals of diversified classification have been patented as solubilizers, Roark (1938, 1940). More recently, La Due (1938) tested several chemicals and concluded that certain ketones possessed special merit as solubilizers. Cressman (1938) suggested a mixture of 30 per cent trichlorethylene and 70 per cent dibutylphthalate as a solubilizer for an extract of timbo. Boyce *et al.* (1940) in experiments for the control of black scale, *Saissetia oleae* (Bern.), showed that true solutions of the extracts of rotenone-bearing roots in oil were much more effective than dispersions of the ground root in oil or certain incompatible solubilizer—extract—oil mixtures wherein

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[4] The use of dibutylphthalate was mentioned in an unpublished manuscript by R. H. Smith. The manuscript is on file at the University of California, Los Angeles.

[5] United States Patent No. 1,786,125.

a phase of unknown composition separated. As suitable solubilizers dibutylphthalate, 2(4-tert.-butylphenoxy) ethanol and an oil-soluble phenolic resin known as *Cardolite*[6] were suggested. In studies with the California red scale Ebeling (1940) found that two solubilizers namely, 2(4-tert.-butylphenoxy) ethanol and *cardolite* were capable of maintaining a true solution of the extracts where larger dosages of oil are necessary. *Cardolite* was found to have the most value in the control of the red scale because of less interference with the depositing properties of the oil in the emulsion.

In the studies with solubilizers it became evident that an evaluation of the compatibility of the solubilizer—extract—petroleum oil mixtures was very essential. Incompatibility very frequently led to disaster not only from the standpoint of insect control but also from the standpoint of mechanical difficulties with the spraying equipment. The additions of petroleum oil to certain solubilizer—extract solutions caused heterogeneity, and when this mixture is agitated in a spray rig a mechanical separation of the phases sometimes occurs. Occasionally one of the phases,[7] of a gummy consistency, sticks the valves and causes interference in the functioning of the pumps.

Rotenone-bearing roots are extracted commercially with certain low-boiling solvents such as ethylenedichloride and trichlorethylene. Solvent-free extracts when properly prepared are homogeneous solid or semi-solid solutions that vary in color and consistency depending upon the source of the root and the solvent employed. The extract (total extractives) consists chemically of rotenone, the rotenoids, the solvent-soluble resins and other constituents. The extracts of the rotenone-bearing roots employed in these experimental studies were extracted with ethylenedichloride.

The term "solubilizer" or "mutual solvent" may be defined as a substance capable, when used in certain proportions, of effecting true solvents of the two immiscible components, namely, the petroleum oil and the extract of the rotenone-bearing root. In all, the systems which have been studied consist of three components and possess the following characteristics. The two liquids, petroleum oil and solubilizer, are miscible in all proportions. The solubilizer and extract are miscible in nearly all proportions; with certain solutions, after long standing and where the concentration of the extract exceeds 35 to 40 per cent, the rotenone and rotenoids crystallize. The two liquids, petroleum oil and extract are only very slightly miscible. For the purpose of simplicity in these systems it has been assumed that the extract functions as a single component and that the whole extract takes part in the real equilibrium. More will be said concerning the behavior of the extracts in the equilibrium later in the paper.

A good qualitative determination and a fair quantitative estimation of the compatibility can be ascertained by titrating solutions of an extract in a given solubilizer with the desired oil component and computing the percentage composition of the components at the plait point or critical point. By plotting the data on triangular coordinate paper a curve, or curves, are obtained which separates the homogeneous from the heterogeneous compositions.

It is believed that the time and the maximum temperature of digestion of the extract—solubilizer solution were factors in the compatibility of the mixtures. Such conclusions were found to be fallacies since the same difference in percentage oil at the plait point could be obtained as a result of different rates of titration. An extract—solubilizer solution will take more oil when titrated rapidly than when titrated slowly. If rapid titrations are avoided fairly uniform results can be expected.

The accuracy of the determination of these three-component solubility curves depends upon the sharp detection of the plait point which in the judgment of the analyst is at best somewhat variable. When the addition of large percentages of oil is necessary to cause heterogeneity, the plait point is very indistinct; however, with such mixtures a small addition of oil past the plait point does not materially affect the position of the curve or the validity of the conclusion.

The data presented in the tables were based upon a temperature of 25° C. Whenever possible, the values were obtained by interpolation from temperature curves. A critical point is determined near 20° C.

[6] *Cardolite* is a formaldehyde condensation product of cardanol, a constituent of cashew nutshell liquid.

[7] The chemical composition of such phases is not known.

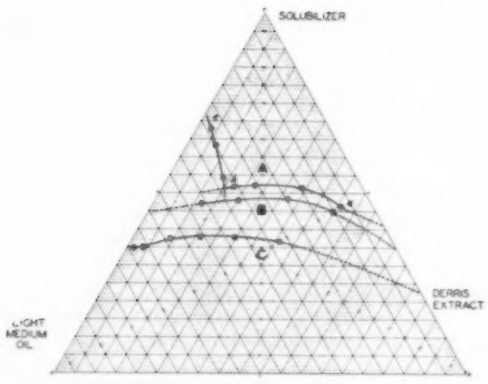

FIG. 1.—Miscibility of a light-medium oil—derris extract (33% rotenone)—solubilizers, A-diphenyl-oxide, B-oil of sassafras and C-methyl-n-amylketone.

The temperature is raised, a further addition of oil is made and the solution is cooled gradually to the critical point. This technique is repeated to obtain sufficient data to determine accurately the value for 25°C. In the case of certain compositions and with certain solubilizers this technique is not satisfactory because the phase separating at the critical point does not readily redissolve when the mixture is heated. In these instances it is necessary to employ several samples titrated at difference temperatures.

This method for determining the compatibility of extract—solubilizer—petroleum oil mixtures is not without its limitations in technique and reliability. It is believed, however, to be adequate from the standpoint of general usage and practicability.

THREE-COMPONENT SOLUBILITY CURVES AS OBTAINED WITH DIFFERENT SOLUBILIZERS.—Many chemicals of different classes have been tested by inspection methods for possible value as solubilizers. Several possessed undesirable physical and chemical properties such as excessive volatility and water solubility. Some possessed phytotoxic properties and other stabilized emulsions to the extent that low oil deposits and poor insect control often resulted. The number of potential solubilizers is so large that it has not been possible to study any one chemical in much detail.

Miscibility curves have been determined with several solubilizers of different chemical classification. The data are summarized in table 1 and curves are given in figures 1, 2 and 3.

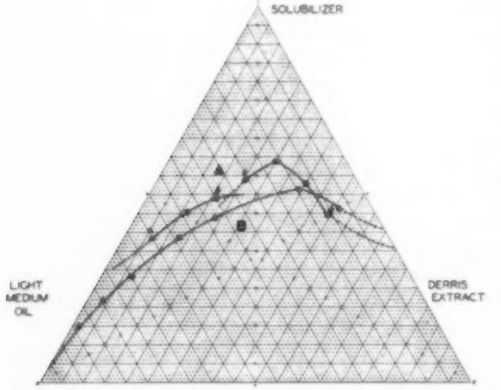

FIG. 2.—Miscibility of a light-medium oil—derris extract (33% rotenone)—solubilizers, A-dibutyl-phthalate and B-2(4-tert.-butylphenoxy) ethanol.

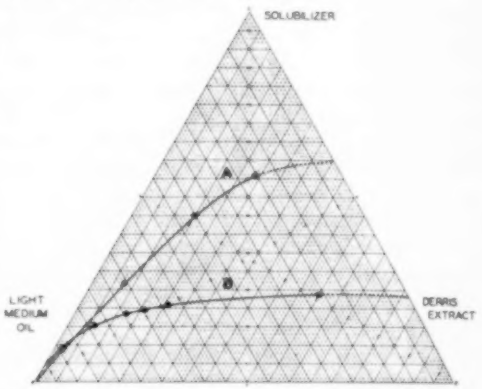

FIG. 3.—Miscibility of a light-medium oil—derris extract (33% rotenone)—solubilizers, A-*Cardolite* and B-diamylphenol.

The derris extract used in all the determinations contained about 33 per cent rotenone and the petroleum oil was a light-medium grade spray oil of 92 per cent unsulfonatable residue (U.R.). The specifications of several petroleum oils are presented in table 2.

The curves in figures 1, 2, and 3 separate the homogeneous mixtures above the curve from the heterogeneous mixtures below the curve.

In figure 1 along curve *ab* of the diphenyloxide—extract—oil system a heavy liquid phase separates, while along the curve *bc* a semi-solid phase of different character separates. Along the curves for oil of sassafras and methyl-n-amylketone heavier liquid phases separate when the initial percentage of the extract in the solubilizer exceeds 30 per cent. Below this

Table 1.—Miscibility of a light-medium grade[1] petroleum oil with solutions of derris extract[2] in several solubilizers at 25° C.

SOLUBILIZER	PERCENTAGE OIL BY WEIGHT AT PLAIT POINT											
	Percentage of a derris extract by weight in solubilizer											
	5	10	15	20	22.5	25	27.5	30	40	45	50	70
Diphenyloxide	28.8	29.9	(31.2)[3]	32.5	(33.5)	30.8	(28.0)	25.7	14.7		8.0	
Methyl-n-amylketone	63.6	61.4	(57.0)	53.5	(51.2)	(49.2)	(47.5)	46.2	37.6		27.3	
2(4-tert.-butylphenoxy) ethanol		83.5	74.6	64.9	(56.0)	48.8	(43.5)	37.8	14.5		7.7	
Dibutylphthalate			55.0	43.7	(38.5)	35.0	26.0	16.3	12.1		11.1	
Oil of sassafras			(46.0)	41.2	(39.0)	(36.5)	(34.2)	31.9	19.6		10.3	
Diamylphenol				88.7		(83.0)		78.3	69.4	64.8	58.3	21.2
Cardolite[4]			>98.0	89.3	65.8	40.3	(29.0)	20.6				

[1] Light-medium #3 grade, 92 U.R. For specifications see table 2.
[2] Derris extract contained about 33 per cent rotenone.
[3] Values in parenthesis were interpolated.
[4] A formaldehyde condensation product of cardanol, a constituent of cashew nutshell liquid.

percentage the character of the separating phase changes.

All solutions of the extracts in the solubilizers, with the exception of *Cardolite*, were prepared by careful digestion at temperatures not exceeding 100° C. for a period of 3 to 5 minutes. After this digestion the solutions were rapidly cooled in an ice bath to about 20° C. The technique of preparation of the *Cardolite* mixtures was of necessity somewhat different. A small amount of the oil under consideration was added to a given weight of *Cardolite*. This oil—solubilizer mixture was carefully heated with agitation to a temperature of 125° C. The desired weight of powdered extract was dissolved rapidly and after digesting a few minutes to effect solution it was cooled rapidly. Because of the very viscous condition of the oil—*Cardolite*-extract mixture it was necessary after each addition of oil during titration to warm the mixtures about 20° C. with constant stirring after which the mixture was cooled to observe a possible critical point. In several instances many hours were required to determine a single critical point.

In figure 2 miscibility curves are illustrated for dibutylphthalate and 2(4-tert.-butylphenoxy) ethanol. The ternary system dibutylphthalate—extract—oil is represented by two curves. The character of the phase separating along the curve *ab* was quite different from that separating along the curve *cd*. The phase under *ab* was not prone to redissolve with an increase in temperature and appeared to be a solid. A mechanical separation of the phase revealed it to be a semi-solid resinous substance. Along the curve *cd* a heavier liquid phase separated that readily redissolved with a rise in temperature.

The miscibility of the ternary system 2(4-tert.-butylphenoxy) ethanol—extract—oil is characterized by a continuous smooth curve. It is of interest to note, however, that the phases separating from mixtures that contain less than 25 per cent extract in the solubilizer are different from those separating from the more concentrated mixtures. For example, when the oil is added to a 15 per cent solution of the extract in 2(4-tert.-butylphenoxy) ethanol a semi-solid resinous phase separates as a stable colloidal dispersion that does not readily redissolve with an increase in temperature. When the oil is added to a 30 per cent solution of the extract in 2(4-tert.-butylphenoxy) ethanol an un-

Table 2.—Specifications of the petroleum oils.

GRADE	UNSULFONATABLE RESIDUE U.R.	SPECIFIC GRAVITY 60° F.	VISCOSITY SECONDS (SAYBOLT 100° F.)	DISTILLATION DEGREES FAHRENHEIT				
				10%	25%	50%	75%	90%
Kerosene	95	0.792	30*	389		426		474
Light-medium	98	0.872	71	586	601	627	661	704
Light-medium	92	0.877	69.3	581	601	621	658	695
Light-medium	75	0.882	50.3	471	523	598	663	722
Light-medium	60	0.906	50.8	466	524	603	665	710
Extra Heavy	99+	0.882	244	662	683	710	734	

* Viscosity = thermal 385 seconds 50° F.

stable liquid phase separates that readily redissolves with a rise in temperature.

In figure 3 the miscibility curves for the ternary systems of oil—extract with *Cardolite*, and diamylphenol are illustrated; they are characterized by smooth continuous curves. At the plait points, when oil is added to compositions less than 20 per cent extract in the solubilizer, resinous phases separate that are not prone to redissolve with an increase in temperature. With compositions above 20 per cent of extract in the solubilizer heavier liquid phases separate that readily redissolve with a rise in temperature. As with the other solubilizers, separate systems of curves should be used to characterize the solubility. The curve for *Cardolite* is exceedingly steep; when it is necessary to employ compositions as high as 25 per cent extract in the solubilizer and when oil (about 40 per cent) is added beyond the plait point the resulting mass is very viscous. On the other hand, a 15 per cent solution of the extract in *Cardolite* will dissolve a quantity of oil that exceeds 99 per cent oil in the resultant composition.

With the ternary system diamylphenol—extract—oil, the addition of the oil to a 15 per cent solution of the extract in the solubilizer will cause separation at the plait point of an unstable semi-solid resinous phase that can be separated readily by mechanical means. A 25 per cent solution of extract in diamylphenol will dissolve about 85 per cent oil before the plait point is reached.

The curves in figures 1, 2 and 3 illustrate both the qualitative and the quantitative utilities of the solubilizer. If the amount of chemical necessary to maintain a solution of the components is the only criterion of a good solubilizer then none of the compounds is ideal. Our data indicate that *Cardolite* is the best of these seven solubilizers for the lower concentrations of the extract, but with higher concentrations, this substance is inferior to certain of the other chemicals. Diamylphenol is the best solubilizer over the entire range of concentrations, while 2(4-tert.-butylphenoxy) ethanol occupies an intermediate position. Dibutylphthalate, while not as efficient as the *Cardolite*, diamylphenol or 2(4-tert.butylphenoxy) ethanol, is a good solubilizer if used in sufficient quantity. Diphenyloxide, oil of sassafras and methyl-n-amylketone are of little practical value.

Table 3.—Miscibility of several petroleum oils with three derris extract[1]—solubilizer solutions at 25° C.

Petroleum Oil Grade	U.R.[2]	Grams of Oil Miscible with 100 Grams of Extract-Solubilizer Solution at the Critical Point		
		Cardolite + 22.5% extr.	K-58[6] +25% extract	Diamylphenol+ 30% extract
Light-medium[3]	98	170.4	70.53	250.9
Light-medium	92	192.7	96.6	115
Light-medium	75	350	388.6	184
Light-medium	60	>500	>500	>500
Extra heavy[4]	98	48.3	13.13	234.8
Kerosene[5]	95	129.6	186.8	298.6

[1] Derris extract contained about 33 per cent rotenone.
[2] Unsulfonatable residue.
[3] For specifications see table 2. The light-medium oils differ only in the degree of sulfonation.
[4] Oil not classified as a spray oil. A medicinal oil known under the trade name, *Nujol*.
[5] Known under the trade name, *Pearl oil*.
[6] K-58 = 2(4-tert.-butylphenoxy) ethanol.

Table 4.—Miscibility of kerosene with solutions of a derris extract[1] in three solubilizers at 25° C.

Percentage Extract in Solvent by Weight	Percentage Kerosene, by Weight, at Plait Point		
	Cardolite[2]	K-58[3]	Diamylphenol
15	>98.0	79.3	85.5
20	67.9	(72.5)[4]	(81.0)
22.5	56.4	(68.0)	(79.5)
25	<50.0	65.1	(78.0)
30		55.3	74.9
40		31.3	(68.0)
60			50.5

[1] Derris extract contained about 33% rotenone.
[2] *Cardolite* is a formaldehyde condensation product of cardanol, a constituent of cashew nutshell liquid.
[3] K-58 is 2 (4-tert.-butylphenoxy) ethanol.
[4] Values in parenthesis were interpolated.

Miscibility of Extract-Solubilizer Mixtures in Different Oils.—Data are summarized in table 3 which show the effect of the grade, that is heaviness as reflected by distillation range and U.R., that is refinement as reflected by unsulfonatable residue of the petroleum oil on its compatibility with the extract—solubilizer mixture. The specifications of the oils have been presented in table 2. Within the same grade of oil the lower the U.R. value, the greater the amount of oil that can be added to a given solution of solubilizer plus extract before the plait point is reached. The unsaturated hydrocarbons aid materially in preventing the separation of phases.

The more volatile petroleum oil fractions of the kerosene type have greater relative compatibility with extract—solu-

bilizer solutions than the heavier fractions.

In table 4 data are given for the miscibility of kerosene with solutions of the derris extract in the solubilizers *Cardolite*, diamylphenol and 2(4-tert.-butylphenoxy) ethanol. The data for these ternary systems are plotted in figure 4. The general relationship of the curves for these solubilizers is the same as was obtained with light-medium oil—solubilizer—extract curves presented in figures 2 and 3.

MISCIBILITY OF A LIGHT-MEDIUM OIL WITH SOLUTIONS OF SEVERAL EXTRACTS IN 2(4-TERT.-BUTYLPHENOXY) ETHANOL.—In the data presented thus far, a derris extract containing about 33 per cent rotenone has been employed. Extracts of rotenone-bearing roots from similar as well as different sources may vary considerably in rotenone content. It was of interest to compare the solubility of a few extracts that vary in their percentage of rotenone with a given solubilizer, 2(4-tert.-butylphenoxy) ethanol, and a light-medium oil (92 U.R.). The data are presented in table 5.

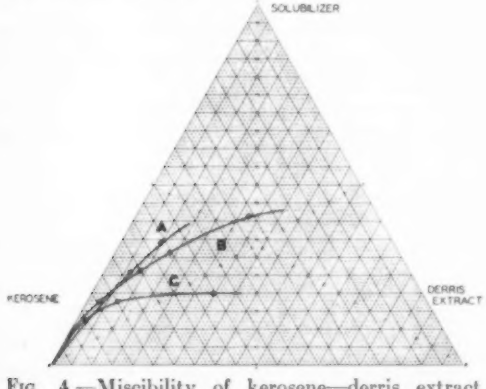

FIG. 4.—Miscibility of kerosene—derris extract (33% rotenone)—solubilizers, A-*Cardolite*, B-2(4-tert.-butylphenoxy) ethanol and C-diamylphenol.

It is apparent from these data that the miscibility or compatibility of the extract is not a function of the rotenone content. A derris extract that contains 40 per cent rotenone is just as soluble as a similar extract that contains 20 per cent. Likewise, a timbo extract containing 9.25 per cent rotenone is just as compatible as one containing 27 per cent rotenone. The solubility of cube extract compares favorably with a derris extract of similar rotenone content. The differences among the data in table 5 are not numerically large and

Table 5.—Miscibility of a light-medium oil[1] with solutions of derris, cube and timbo extracts in K-58[2] at 25° C.

Extract	Percentage[3] Rotenone in Extract	Percentage Oil by Weight at Plait Point: Percentage by weight of extract in K-58[2] 15	20	25	30	40
Derris	20	86.4	66.4	47.3	30.0	15.3
Derris	33	74.6	64.9	48.8	37.8	14.5
Derris	35–40	83.1	(66.0)[4]	47.5	(32.0)	15.3
Cube	40	73.4	(55.0)	42.4	(30.0)	15.6
Timbo	9.25	68.9	(53.0)	40.9	28.8	
Timbo	27	73.1	(56.0)	40.7	29.2	

[1] Light-medium #3 grade, 92 U.R. For specifications see Table 3.
[2] K-58 is 2 (4-tert.-butylphenoxy) ethanol.
[3] Percentage rotenone approximately accurate.
[4] Values in parenthesis were interpolated.

can in no way be related to rotenone. Some other constituent, that is present in the extracts in a similar percentage composition, is a more important factor in the miscibility determinations.

SOLUBILITY OF ROTENONE *versus* THE EXTRACTS.—Because these extracts are homogeneous solid or semi-solid solutions it was considered a possibility that the resinous constituents of the extracts might be of importance to the solubility relationships. In table 6 data are given for the solubility of chemically pure rotenone (M. P. 163° C.) with a light-medium oil and the two solubilizers 2(4-tert.-butylphenoxy) ethanol and diamylphenol. For comparative purposes the data for these two solubilizers, as presented in table 1, were recalculated for percentage composition on the basis of the rotenone content of the extract and on the assumption that the other constituents of the extract are extrinsic to the equilibrium. The data are plotted in figure 5. To facilitate comparisons vertical lines have been drawn to several percentage compositions of the rotenone and solubilizer. From comparison of the hypothetical curve with the actual curve it is evident that pure crystalline rotenone is very much more soluble than the rotenone in the presence of the other extractive constituents. This relationship is further evidence that some constituent in the extract other than rotenone is the chief factor in the compatibility of the extract mixtures.

DISCUSSION.—Throughout this paper mention has been made concerning the composition of the phases that separate at the plait point. At the outset, it was assumed that the extract functioned as a

Table 6.—Miscibility of a light-medium grade oil with solutions of rotenone in two solubilizers.

Solubilizer	Hypothetical[1] Rotenone		Chemically Pure[2] Rotenone	
	Percentage rotenone by wt.	Percentage oil at plait point	Percentage rotenone by wt.	Percentage oil at plait point
K-58 = 2(4-tert.-butylphenoxy) ethanol	3.9	84.4	8.0	82.9
	5.8	76.5	10.0	76.6
	8.0	68.0	13.0	(65.0)[3]
	10.4	53.0	15.2	57.6
	13.0	36.2	18.9	(45.0)
	18.9	18.7	25.0	30.2
	25.9	11.0		
Diamylphenol	8.0	89.6	10.0	>96
	13.0	81.7	25	>96
	18.9	75.4	25.9	>96
	22.0	72.1	30	95.8
	25.9	67.4	45	(85.5)
	45.0	33.0	50	82.7

[1] Values were computed from the data presented in Table 1. Based upon a 33 per cent extract, it was assumed for comparative purposes that the other constituents of the extract were extrinsic.

[2] The rotenone was recrystallized from carbon tetrachloride and melted sharply at 163° C.

[3] Values in parenthesis were interpolated.

true component and that the whole extract took part in the real equilibrium. If the extract behaved as a single component in the system it would be expected that the phases, exclusive of the vapor phase, would contain various percentage compositions of the whole extract.

Little is known about the composition of the phases that separate in the condition of heterogeneity but it appears that the extract is really more than one component in the systems. It has been indicated that the phases which separate when oil is added to low concentrations of derris extract in a solubilizer are different from those separating from the higher concentrations. The fact that these separating phases respond differently in solubility with temperature changes is direct evidence that their compositions are different.

To a 16.67 per cent solution of a derris extract (33 per cent rotenone) in diamylphenol, kerosene was added to a percentage composition of oil past the plait point. The precipitate was filtered, washed with kerosene and dried. The material was only slightly soluble in hot carbon tetrachloride and efforts to crystallize rotenone or other crystalline rotenoids from this solvent failed. On the other hand, in a solution of a similar weight of extract dissolved in hot carbon tetrachloride alone and filtered, rotenone crystallized readily. One of the resinous constituents in the extract is only slightly soluble in hot carbon tetrachloride and for this reason the filtering procedure was essential. The phase separating from the diamylphenol—extract—oil mixture appeared, when concentrated, as a dark-brown, semi-solid, noncrystalline substance. This is probably one or more of the ethylenedichloride-soluble resins of the root.

In a similar manner, to a 16.67 per cent solution of a derris extract (33 per cent rotenone) in 2(4-tert.-butylphenoxy) ethanol, kerosene was added past the plait point. The rather stable colloid was difficult to separate but the phase separating was, in appearance and behavior, identical to the phase separating from the diamylphenol—extract—oil mixture previously discussed. The filtrate after separation of the resinous phase was miscible at infinite dilution with kerosene.

Return now to a consideration of the discussion of the ternary systems as plotted in figures 1, 2 and 3 and also to a consideration of other miscibility curves for systems of oil—extract—solubilizer wherein a plait point or critical point is employed as a criterion of compatibility and usefulness. The importance of knowing the composition of the heterogeneous systems is of considerable practical importance. Within the range of certain concentrations, where this resinous phase is

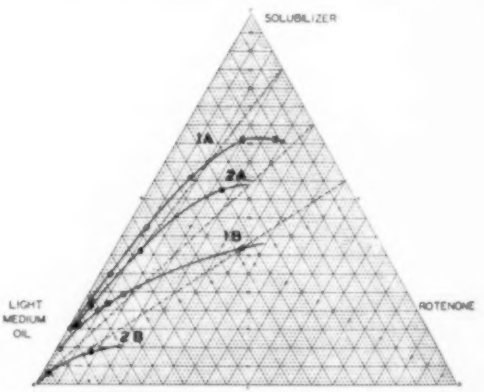

FIG. 5.—Solubility of a light-medium oil—hypothetical rotenone (1) and c.p. rotenone (2)—solubilizers, A-2(4-tert.-butylphenoxy) ethanol and B-diamylphenol.

possibly devoid of rotenone, it is probable that experimentation will show such solutions to be toxic to insects in spite of the existing heterogeneity. There is laboratory evidence on the California red scale, *Aonidiella aurantii* (Mask.), and field evidence

on black scale *Saissettia oleae* (Bern.) to substantiate this statement.

These studies with solubilizers have been very preliminary and exploratory in nature. It is hoped that other workers will make a more detailed study of this subject.

SUMMARY.—A method has been given for the determination of the miscibility of the ternary systems, rotenone-bearing extracts—petroleum oils—solubilizers. For any solubilizer a series of plait points were determined experimentally. By plotting these values on triangular coordinate paper, curves are obtained which delimit homogeneous and heterogeneous mixtures.

Three-component solubility curves have been determined for systems of a light-medium oil—derris extract (33 per cent rotenone)—solubilizers that are representative of different chemical classes. The solubilizers included in the study were diphenyloxide, oil of sassafras, methyl-n-amylketone, dibutylphthalate, 2(4-tert.-butylphenoxy) ethanol, *Cardolite* and diamylphenol.

The effect of the grade and unsulfonatable residue (U.R.) of the petroleum oil on the miscibility of the three components of the ternary systems has been determined. The lower the U.R. value of the same grade of oil the greater the amount that can be added to a given solution of solubilizer plus extract. The more volatile fractions of the kerosene grade have greater relative compatibility with extract—solubilizer solutions than the heavier fractions.

It has been found that the compatibility of extracts of rotenone-bearing roots that differ in source is not a function of the rotenone content.

Chemically pure rotenone is much more soluble in solutions of a light-medium petroleum oil and 2(4-tert.-butylphenoxy) ethanol than similar quantities of rotenone in the presence of the other constituents of the extract. It has been suggested that some constituent in the extract other than rotenone is the chief factor in determining the compatibility of the mixtures.

The desirability of knowing the composition of the phases that separate in the state of heterogeneity of the systems has been stressed. Within certain ranges of concentrations of the systems a phase separates what appears to be one or more of the ethylenedichloride-soluble resins of the root.

Toxicological evidence points to the fact that certain heterogeneous compositions are effective for the control of certain insects, possibly because the active constituents of the extract are in solution.[1]

[1] It is a pleasure to acknowledge the valuable assitance rendered on certain aspects of this work by R. Beier, G. L. McCall and J. P. LaDue of this institution. The cooperation of individuals of various industrial organizations who prepared or supplied certain materials used in these studies is greatly appreciated. Dr. W. J. Haude, John Powell Co., prepared the extracts of the rotenone-bearing roots; A. J. Flebut, California Spray Chemical Corporation, prepared the petroleum oils; W. W. Allen, The Dow Chemical Company, supplied the chemicals, 2(4-tert.-butylphenoxy) ethanol and diphenyloxide; and W. F. Hoffman, Irvington Varnish and Insulator Corporation, supplied the *Cardolite*.

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Mr. S. A. Rohwer, a member of the Bureau of Entomology since 1929 and for several years past an Assistant Chief of the Bureau of Entomology and Plant Quarantine, has been placed in charge of all the regulatory work of the bureau. Mr. Rohwer has had experience in this field, having been Assistant Chief of the former Bureau of Plant Quarantine and Control Administration.

Mr. Wm. L. Popham, also an Assistant Chief of the Bureau, will be in charge of control operations.

Physiological Effects of Petroleum Oil Sprays on Citrus

P. W. Rohrbaugh,[1] *Ontario, California*

The use of petroleum products on citrus apparently started with the use of kerosene about 1880. Hubbard (1882, 1885) in reporting on the use of kerosene on the orange highly recommended the kerosene milk emulsions. He stated that oranges were slightly injured by kerosene and that the heat of the sun increased the injurious

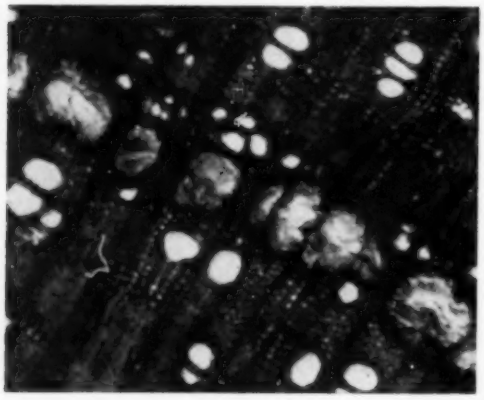

Fig. 1[2].—Cross section of lemon twig showing large irregular holes filled with light yellow gum. These were caused by unsaturated hydrocarbons in spray oils.

effects. Many leaves were made to fall but they took many insects with them. Volck (1903) reported on the use of distillates.

Distillates and various other petroleum products were used thereafter to some extent but not consistently and not without frequent injury. Gray & de Ong (1926) reported that they had in 1915 found a relationship between the degree of refining of petroleum with sulfuric acid and plant tolerance. Volck came out in 1924 with emulsions of highly refined oils which had had the unsaturated hydrocarbons removed with sulfuric acid and sulfur dioxide.

These emulsions were much less injurious and they came to be the most commonly used insecticides for citrus.

At no time, however, has any petroleum oil been accepted as a completely satisfactory insecticide either from the standpoint of its ability to kill certain insects or from the standpoint of the plant's reaction to it. As time has passed and more experience and data have accumulated the limits which can be expected in the percentage of insect kill and the detrimental effects to the tree, have been quite well established. If oil heavy enough to kill all insects is applied, tree injury must be expected.

The injurious effects of petroleum spray oils on citrus are now considered to be largely due to two factors. The first factor is a chemical burning by the unsaturated hydrocarbon molecules or other toxic molecules in the oil. Unsaturated hydrocarbon molecules are very toxic to the cells of the plant often killing them. Killing of the cells of the leaves causes dropping of the leaves. The cambium of the branches may be killed when the oil penetrates that deeply into the bark. The depth of penetration of a given oil depends upon the quantity of oil put on the tree. The more oil put on the tree the deeper it goes into the tissue. When the cambium of a tree is injured it may be only in local areas as shown in figures 1 and 2. In this case the twig may go on growing without serious external evidence of injury or in other cases large areas of bark or even the whole tree may be killed.

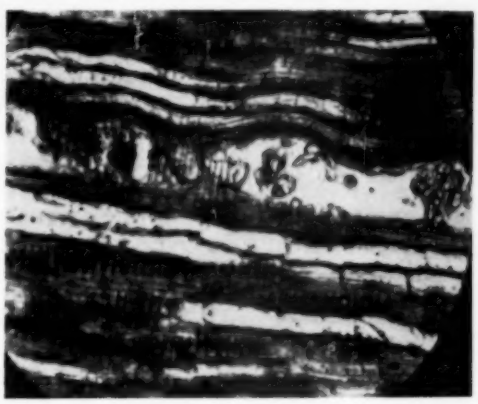

Fig. 2.—Longitudinal section of twig shown in figure 1.

This type of injury has largely been

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[2] Several of the figures appearing herewith were published (1934) in a paper by the author in *Plant Physiology*.

eliminated by using the highly refined oils most of which do not contain more than six or eight per cent of these unsaturates at most and often not more than two per cent of unsaturates. It is believed that these unsaturated hydrocarbons are responsible for practically all leaf drop and any other obvious injuries occurring within a few days after spraying.

The second factor in injury to citrus by oil sprays seems to be the result of the plugging of the intercellular spaces and the surrounding of the plant cells with oils (Fig. 3) which prevent the movement of gases such as carbon dioxide and oxygen out of and into the cells. This causes a dormant effect on the tree and some limbs may eventually die. The gas move-

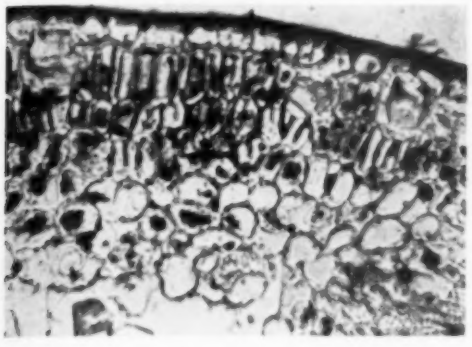

FIG. 3.—Long dark areas are petroleum spray oil between palisade cells of upper surface of orange leaf.

ments are necessary to the normal respiratory and photosynthetic function of the cells. Little information about the location of this oil or the time it stayed in the tissues was available until the work of Knight *et al.* (1929) and Rohrbaugh (1934). Photomicrographs show the oil between the cells of the leaf (Fig. 3), in the cortex or bark of the twig (Fig. 4) and down in the woody part of the stem. (Fig. 5.)

When oil is put on a tree it goes into it through the cuticle on the upper side of the leaf or through both the cuticle and the stomata on the lower side of the leaf or through the cuticle and lenticles of the smaller stems or through the corky bark of the larger branches and trunk. This oil apparently goes in only by capillarity and enters any or all intercellular spaces as it gets to them but advances only so long as there is a supply of oil on the surface. No valid evidence has been found to indicate

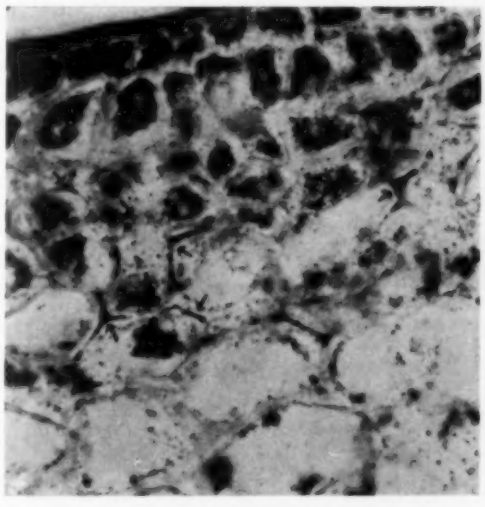

FIG. 4.—Section of orange twig showing spray oil between cells of bark or young twig.

that the spray oil moves except by capillarity between the cells. It seems logical to assume however that small portions of the oil especially the lighter oils are soluble in water and will dissolve in the plant liquids. It must also be assumed that some of the lighter fractions of these oils will volatilize and move through the plant as a gas. In this gaseous state they would be much more easily and readily oxidized to other products which might be toxic to the plant. It is possible that low boiling fractions of the oil may in this way become a source of some injury.

In work done in 1937 and 1938 by sectioning and staining the oil in leaves and twigs of citrus, the writer has found that

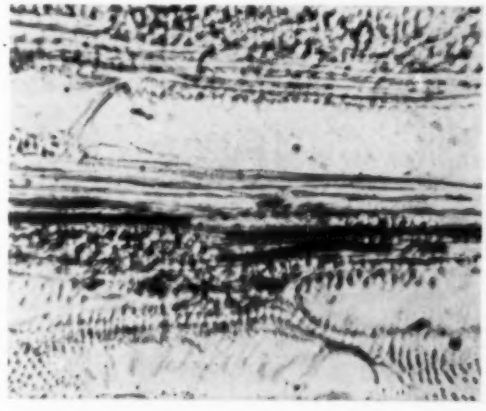

FIG. 5.—Longitudinal section of woody part of lemon stem showing spray oil in wood fibers.

emulsions of the so-called soluble oils or oils containing oil-soluble spreaders in them invariably spread out on the walls of the cells much more than the emulsions with water-soluble spreaders. They tend to spread out in much thinner films on the cell walls rather than to form globules in the intercellular spaces. However, no evidence has been presented to indicate that one of these types causes any more injury than the other.

FIG. 6.—Green spots left by petroleum spray oil on fruit.

The types of injury occurring from oil sprays have been discussed by numerous writers including Ebeling *et al.* (1936), Hubbard (1885), de Ong *et al.* (1927), Woglum *et al.* (1928), Ohsaki & Hayano (1931), Zanotti (1933), Knight *et al.* (1929) and Yothers (1918).

The main detrimental effects pointed out by these writers are:

Leaf drop
Fruit burn
Dead wood
Rough textured fruit
Low quality—low sugars, acids, lack of flavor
Increased granulation
Fruit drop
Interference with coloring (Fig. 6)
Crop reduction
Upset of normal blossoming
Fruit more susceptible to water rot and decay in wet weather.

Other writers have made claims of various beneficial effects of oil sprays such as larger fruit, larger leaves, better color, protection from wind injury, etc., but most, at least, of these claims of benefits are not believed to be well founded and certainly are not significant under California conditions.

Some of the more fundamental effects of oil on citrus have been worked on by Knight *et al.* (1929), who have found indications of greatly increased respiration over two weeks time following heavy applications of oil. It seems rather difficult however to reconcile this with other observations where trees tend toward a much more dormant condition after heavy sprays. It would seem more logical to think that the respiratory activity would be lowered due to the cells of the plant being surrounded by oil thus keeping out the oxygen and keeping in the carbon dioxide. This is in keeping with the same authors findings in which they report greatly decreased transpiration. It is possible, however, to see how oil which injures the plant might stimulate or irritate those cells not surrounded with oil and thus increase the total respiratory rate.

These authors also found that the plant's ability to produce starch in its leaves was greatly hindered by application of oil spray.

Kerosene has been used on citrus frequently but not extensively during the last forty years. Today kerosene is again showing promise of becoming an important factor in citrus insect control. At the University of California Citrus Experiment Station Ebeling has recently shown that by dissolving derris root extracts in kerosene by means of a mutual solvent and using about 8 to 10 per cent of this in water as a spray good control of red scale is obtained.

Many have wondered what the effect of this kerosene may be on the citrus tree. Hubbard (1882, 1885) mentions favorably the use of kerosene sprays on oranges. Yothers (1918) mentions its use in 1913. Moore & Graham (1918) made a study of the toxicity of kerosenes to both insects and plants. They found the light fraction most toxic to the plant and the heaviest fraction most toxic to the insect.

Gray & de Ong (1926) used four different kerosenes containing different quantities of unsaturates. One of these caused slight leaf drop; the others caused no visible injury. In the opinion of the writer

not enough observations have been made on the use of our present day kerosenes on citrus with applications of 8 to 10 per cent to be able to say that they are entirely non-injurious to citrus. From the information now available it appears that the ordinary kerosenes on the market having an unsulfonatable residue of 96 or above are relatively safe under most conditions but careful observations should be made for indications of cambium injury. 7-23-41.

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Factors Affecting the Absorption and Retention of Hydrocyanic Acid by Citrus Leaves and Fruits[1,2]

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Fumigation with HCN for the control of insects has been a general practice in California since 1886. The fumigation dosages now used in California are much higher than those used many years ago, owing to the greater tolerance of resistance to HCN fumigation that has developed in three of the most important scale insects (Quayle 1938). The limiting factor to increasing indefinitely the dosages of HCN is the effect of the gas on the tree or fruit. There are certain conditions which, when present, may account for fumigation injury, but at times the injury may appear for no apparent reason. The object of the experiments reported in this paper was to determine, if possible, whether fumigation injury is directly related to the amount of HCN absorbed during the fumigation period and to the length of time that HCN remains in the tissues.

MATERIALS AND METHODS.—The description of methods for the recovery and determination of HCN from fumigated tissues and the results of preliminary studies on the absorption and retention of HCN by citrus tissues have been previously published by Bartholomew & Raby (1935) and by Bartholomew, Sinclair & Janes (1939). The fruits of different ages and the mature leaves used in these experiments were of the Valencia orange variety in all cases. Immature fruits are referred to as "green" (in color)

[1] Paper no. 445, University of California Citrus Experiment Station, Riverside, California.

[2] A more detailed report on these and other results is being prepared for publication in Hilgardia.

or "immature yellow." The age and size of the fruits are indicated by the dates on which the experiments were performed. Each sample of leaves weighed 200 grams and consisted of a composite of leaves from several trees, except in the case of fumigation of a single tree in the field. Each paired sample of fruit weighed approximately the same and, as nearly as possible, was composed of fruits of the same age and size, except in instances in which the behavior of green and mature fruits was being compared. The number of fruits per sample ranged from 12 to 35. The leaves and fruits were detached either before or after treatment, brought to the laboratory, and fumigated in a metal fumatorium (100 cu. ft. capacity) or they were fumigated *in situ* in the field under regular commercial fumigation canvas tents. The dosage in the fumatorium was 8 ml. of liquid HCN per 100 cu. ft. of space, while a 20-ml. schedule per unit (100 cu. ft.) was used in the tents. The lengths of the fumigation periods were 40 and 45 minutes, respectively, for fumatorium and tents. The average decrease in concentration of HCN in the fumatorium during the fumigation period was only 8.3 per cent while in the tents the decrease was approximately 95 per cent.

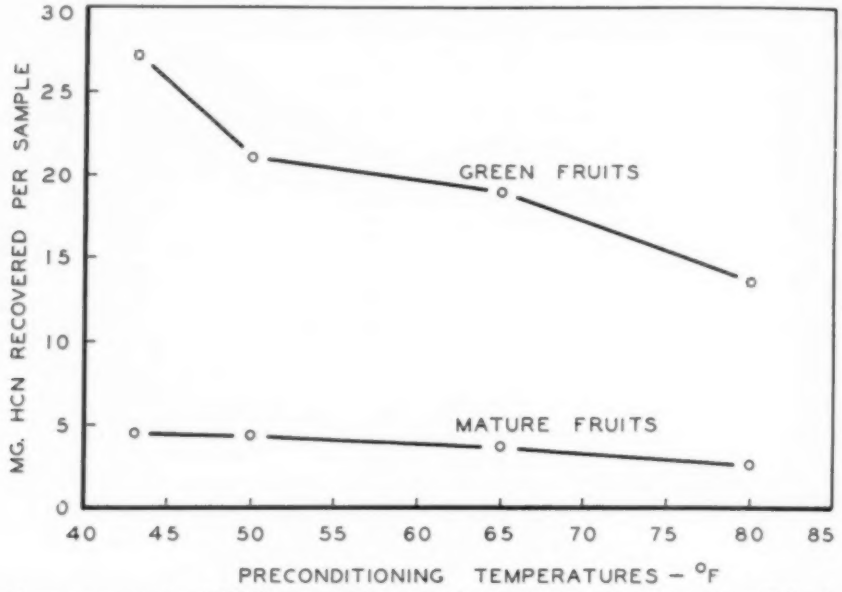

FIG. 1.—Average amounts of HCN recovered per total sample of green and mature Valencia orange fruits which were pre-conditioned overnight at the given temperatures and then fumigated in the fumatorium.

PRECONDITIONING TEMPERATURES AND THE ABSORPTION OF HCN.—Quayle & Rohrbaugh (1934) obtained a higher kill of red scale and greater injury to young rooted lemon cuttings when preconditioned for at least 4 hours at 50° F. than at 90° F. before being fumigated.

The results presented here show that green (Sept. 26 to Oct. 31) and mature (Oct. 14 to Nov. 17) fruits absorbed decreasingly less HCN when they were preconditioned at 43°, 50°, 65°, and 80° F. before being fumigated. The average amounts of HCN recovered from the fruits preconditioned at the different temperatures were 27.1, 20.9, 18.9, and 13.5 mg., respectively, for the green fruit, and 4.7, 4.4, 3.5, and 2.6 mg., respectively, for the mature fruit (Fig. 1). Fumigation injury was much more severe on the green fruits than on the mature fruits, but there was approximately the same amount of injury at each temperature. The results of this experiment indicate that, other factors being equal, injury depends upon the physiological condition of the tissues more than it does upon the amount of HCN which they absorb during the usual fumigation period.

EFFECT OF OIL SPRAY UPON THE ABSORPTION OF HCN.—Although many

exceptions are admitted, growers and fumigators are rather generally of the opinion that an application of oil spray to citrus trees makes them less susceptible to fumigation injury. In February, samples of detached immature yellow fruits were sprayed with a 1 per cent light-medium oil spray in the laboratory and allowed to remain 2 days before being fumigated. When these samples were fumigated they absorbed considerably less HCN than similar samples of unsprayed fruits (Fig. 2).

On March 5, several trees were very thoroughly sprayed with a 1.5 per cent light-medium oil spray of the same viscosity but of a different brand than was used in the laboratory. Between March 6 and May 13, several composite samples of fruits from these trees and similar samples of fruits from near-by unsprayed trees were fumigated in the fumatorium. Between March 11 and 13, 6 corresponding pairs of samples of leaves picked from the same groups of trees were fumigated in the fumatorium. The results of these experiments show that there was no significant difference in the amounts of HCN absorbed by the oil-sprayed and unsprayed fruits and leaves (Fig. 2). None of the unsprayed fruits was injured, but

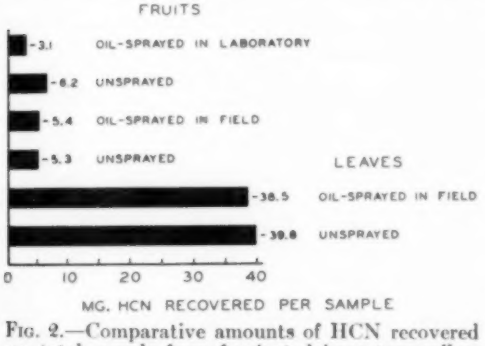

FIG. 2.—Comparative amounts of HCN recovered per total sample from fumigated immature-yellow Valencia orange fruits sprayed with a 1 per cent oil spray in the laboratory and from similar fruits and from mature leaves sprayed with a 1½ per cent oil spray in the field. A precision sprayer was used in the laboratory and a commercial high-pressure sprayer was used in the field. All samples were fumigated in the fumatorium.

6 per cent of the oil-sprayed fruits showed injury.

The 1 per cent oil spray applied in the laboratory retarded the entrance of HCN into the fruits, but the 1.5 per cent oil spray applied in the field had no such effect on either fruits or leaves. It is possible, of course, that the laboratory sprayer applied a heavier coating of oil than the field sprayer. And although two different brands of oil were used, it should be remembered that a 0.5 per cent higher

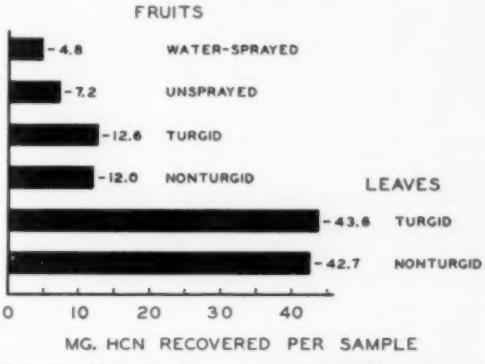

FIG. 3.—Comparative amounts of HCN recovered per sample from fumigated mature water-sprayed and unsprayed fruits; from green turgid and nonturgid fruits; and from turgid and nonturgid mature leaves. All samples were of the Valencia variety and all fumigations were made in the fumatorium.

concentration of oil was used in the field than was used in the laboratory. Furthermore, only outside fruits which naturally received the heaviest coating of oil were chosen for the fumigation tests. It may be added also that approximately 25 gallons of spray were applied to each tree while only 15 to 20 gallons would have ordinarily been applied to trees of this size. From the limited data at hand no further explanation is offered for the latter results, except to say that this may be one of those "many exceptions" which were mentioned that do not conform to the results generally observed. It is evident, however, that in this case the presence of oil spray on the fruits did not prevent 6 per cent of them from being injured while none of the unsprayed fruits was injured.

EFFECT OF EXTERNAL AND INTERNAL MOISTURE ON ABSORPTION OF HCN BY CITRUS TISSUES.—Between May 27 and June 18, paired samples of mature fruits were brought to the laboratory and one sample of each pair was sprayed with water containing a small amount of spreader. The sprayed and unsprayed samples were then simultaneously fumigated at once. The sprayed samples absorbed an average of 4.8 mg. and the unsprayed 7.2 mg. of HCN per sample

(Fig. 3). The sprayed fruits were still moist when taken from the fumatorium so they were washed in distilled water at once and the water was added to the sliced fruits in the distillation flask. Apparently the water film greatly retarded the entrance of HCN into the fruits and the total amount of HCN absorbed by the films and these fruits was only 66 per cent as much as was absorbed by the unsprayed fruits.

These results are of special interest in view of the fact that Lindgren (1941) obtained a greater kill of red scale on infested fruits covered with a film of water than on similar fruits having dry surfaces. With the several possible factors involved it is difficult to harmonize these results with those just mentioned, which show that water-sprayed fruits absorbed less HCN than unsprayed fruits. It seems probable, however, that as the water on the sprayed fruits evaporated it not only tended to cool the fruits and scale but also continued to release HCN which would affect the scale. These results may, in a way, be comparable to those of Quayle & Rohrbaugh (1934) in which they obtained greater kills of red scale which had been preconditioned and fumigated at 50° than at 90° F. In an earlier section of this paper it has been shown that fruits absorb more HCN when preconditioned at a low than at a high temperature; these cool fruits and those in the experiments of Quayle and Rohrbaugh therefore continued to release HCN longer than the warm fruits. It would seem possible then that the greater kill of red scale in both cases may have been at least partially due to temperature effects on the scale and to the increase in length of time during which they were exposed to gaseous HCN.

Between August 21 and September 6, comparative amounts of HCN absorbed by turgid and nonturgid small green fruits were determined. Fruits were made especially turgid by standing their stems in water in a humid chamber for 15 to 20 hours. The control fruits were cut off without stems and placed in an open paper bag outside the humid chamber for the same length of time. The samples of turgid and nonturgid fruits were fumigated in pairs. There was no significant difference in the amount of HCN absorbed—12.6 mg. by the turgid and 12.0 mg. by the nonturgid fruits (Fig. 3).

Between May 14 and 24, tests similar to those made on small green fruits were made on mature leaves. Composite 200-gram samples of leaves from 6 to 8 trees were brought to the laboratory. One sample of each pair was kept in an air-tight container while the other was being wilted. The leaves were wilted until they had lost 15 per cent of their fresh weight by spreading them in a large rectangular wire basket which rested in the top of a cardboard flue (*ca.* 3 ft. high) which stood over a hot plate. About 30 minutes elapsed between the time of picking and the time fumigation began. As with the fruits, the turgid and nonturgid leaves absorbed practically the same amounts of HCN—an average of 43.6 mg. per sample by the turgid and 42.7 mg. per sample by the nonturgid leaves (Fig. 3).

HCN injury to the detached leaves was not determined because they dry so rapidly, but extra samples of fruit were fumigated each time and set aside to be observed for the presence or absence of injury. The older the fruits the less subject they are to HCN injury, and this probably explains why none of the mature water-sprayed fruits and their controls were injured. Injury to the young green fruits, however, was very evident. Regardless of the fact that they absorbed equal amounts of HCN, 84 per cent of the turgid and only 29 per cent of the nonturgid fruits were injured. Furthermore, of the injured fruits, 61 per cent of the turgid and only 7 per cent of the nonturgid fruits were classed as badly injured. These results do not confirm the generally accepted opinion that the greater the amount of HCN absorbed the greater the injury to the tissues, but they do substantiate the view, expressed earlier in this paper, that injury or noninjury to the tissues is more largely governed by their physiological condition than by the amount of HCN which they absorb.

COMPARATIVE AMOUNTS OF HCN ABSORBED BY INLAND AND COASTAL FRUITS.—Comparable samples of fruits were picked from trees in inland and coastal areas: two pairs from each area on each of 8 days between December 5 and 15, and again between January 16 and 27, a total of 64 samples from each area. Each pair of samples (inland and coastal) was fumigated in the fumatorium at the same time.

In this experiment fruits from the coastal area absorbed an average of 24 per cent more HCN in January and 10 per cent more in December than the inland fruits. There were, however, 3 cases in which the inland samples absorbed slightly more HCN than the coastal samples. The January samples absorbed less HCN than the December samples, probably because the fruits were more mature. This was true for the samples from both areas.

be made in coastal areas when it was unsafe to fumigate in inland areas—a very rare condition.

In spite of the fact that the coastal fruits absorbed the most HCN in 1939–40 and the least in 1940–41, they were the ones that were the most severely injured in both instances. As the fruits were examined for injury they were classed as good, or slightly, moderately, and badly injured. The percentages of fruits falling

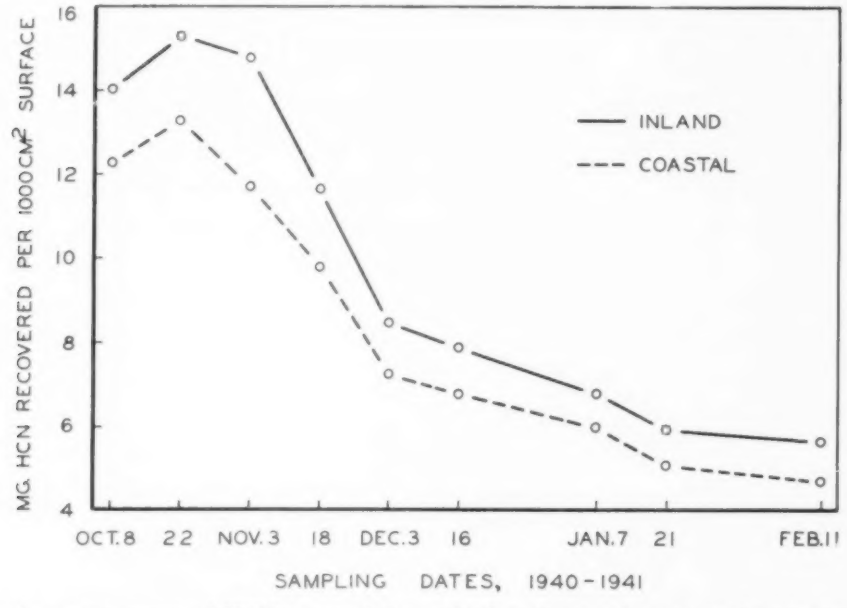

FIG. 4.—Average amounts of HCN recovered from inland and coastal green and immature-yellow Valencia orange fruits fumigated in the fumatorium. The amounts of HCN recovered are expressed as mg. per unit of fruit surface rather than as total mg. per sample. Each point on each curve represents the average recovery of 6 determinations—two for each of 3 inland two for each of 3 coastal groves.

An experiment similar to the one just described was conducted between October 8, 1940, and February 11, 1941. The results are presented in graph form (Fig. 4) because they illustrate very well the decrease in HCN absorption as the fruit increases in maturity. The results are expressed in mg. per 1000 cm.^{2} of fruit surface rather than as mg. per total fruit sample. The fruits picked on February 11, 1941, absorbed approximately only 35 per cent as much HCN as those picked on October 22, 1940. The figure also shows that the inland fruits absorbed more HCN than the coastal fruits—the opposite of the previous year's results. In this connection it is of interest to note that at times during the winter of 1940–41 fumigations could

into each of these classes for the two areas is shown in table 1. These results give further evidence that the physiological con-

Table 1.—Comparison of HCN injury to inland and coastal fruits.

AREA	GOOD	SLIGHTLY INJURED	MODERATELY INJURED	BADLY INJURED	TOTAL INJURED
Fruits picked from December 5, 1939 to January 27, 1940					
Coastal	32	24	16	28	68
Inland	66	25	9	0	34
Fruits picked from October 8, 1940 to February 11, 1941					
Coastal	13	29	17	41	87
Inland	57	34	6	3	43

dition of the fruits rather than the amount of HCN which they absorb determines whether they will or will not be injured by fumigation.

HCN ABSORBED BY LEAVES AND FRUITS FUMIGATED UNDER FIELD CONDITIONS.—Nine trees were fumigated at night and three during the day to determine the effects of environmental conditions on the comparative amounts of HCN absorbed and the extent of injury to the tissues. The trees were fumigated between September 20 and November 14, 1939, and July 23 and August 15, 1940. The first initial recoveries and the lengths of time that the HCN remained in the tissues. Both leaves and fruits absorbed approximately the same amounts of HCN when fumigated at night as when fumigated during the day, which indicates that the stomata do not play an important part in regulating the amount of HCN that enters the tissues. The leaves and fruits on the day-fumigated trees were much

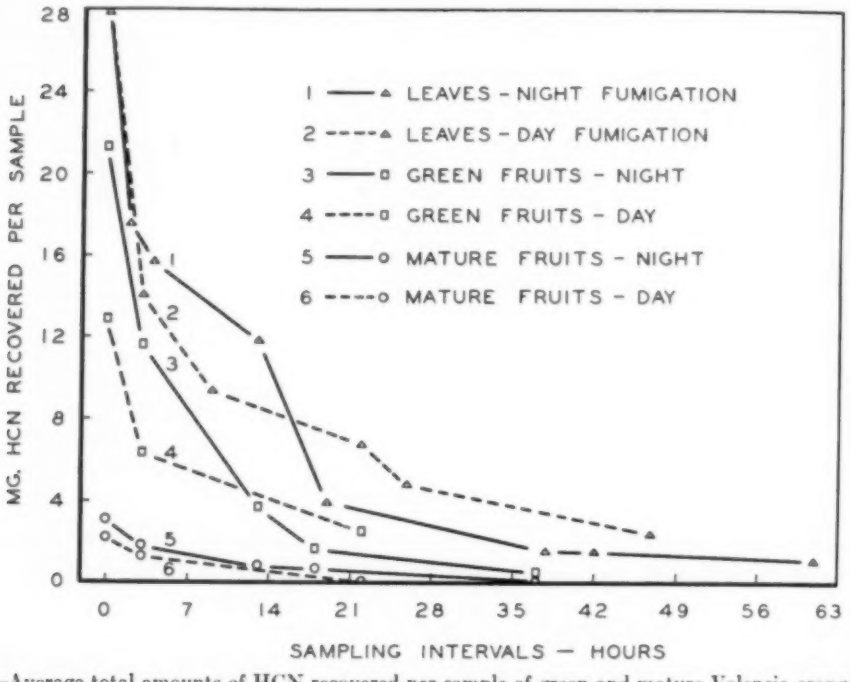

FIG. 5.—Average total amounts of HCN recovered per sample of green and mature Valencia orange fruits and mature leaves from 12 trees fumigated at night or during the day under field conditions. The curves do not show the variations in recoveries from the individual trees but they indicate the trends for comparative initial recoveries from the different samples and for the length of time they retained the HCN.

samples of leaves and fruits were picked immediately after the tents were removed. Other samples were taken at intervals to determine the length of time recoverable HCN would remain in the tissues of the treated trees.

The results of this experiment are expressed as average recoveries from leaves and fruits fumigated at night or during the day (Fig. 5). The recoveries are expressed as mg. per total sample. The amounts of HCN recovered from both leaves and fruits from the different trees differed greatly, because of different environmental and other conditions. The curves in this figure show only the general trends for the comparative amounts of more severely injured than those on the night-fumigated trees. The results of this experiment still further confirm the opinion that the physiological condition of the tissues, rather than the amount of HCN absorbed, is the most important factor in determining whether the tissues will suffer fumigation injury.

SUMMARY.—Green and mature fruits absorbed decreasingly less HCN when preconditioned overnight at 43, 50, 65, and 80° F. Fruits sprayed with a 1 per cent oil spray in the laboratory absorbed less HCN than unsprayed fruits, but similar tests with a 1.5 per cent oil spray in the field showed no appreciable difference. Turgid fruits and leaves absorbed more

HCN than nonturgid fruits and leaves under field conditions, but not under labaratory conditions. Fruits from coastal areas absorbed more HCN than similar fruits from inland areas in 1939–40 but less in 1940–41. In both years however, the coastal fruits were more seriously injured than the inland fruits. The amounts of HCN absorbed by fruits and leaves when fumigated under field conditions during the day or at night were approximately the same, but fruits and leaves fumigated during the day were much more severely injured than those fumigated at night. The results just mentioned indicate that the stomata are not a controlling factor in HCN absorption. Whether or not the fumigated tissues will be injured appears to be governed by the physiological condition of the tissues more than by the amount of HCN absorbed.—7-23-41.

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Comparative Effects of Oil Spray and Hydrocyanic Acid Fumigation on the Composition of Orange Fruits[1]

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The use of oil sprays and hydrocyanic acid (HCN) fumigation for the control of scale insects on citrus trees is so well established as to warrant a study of the effect of these chemicals on the physiology of the tissues of tree and fruit. In fact, it is just as important to know the physiological response of the plant to the continued application of insecticidal materials as to know the physiological response of the insect to the treatment, and the successful use of any chemical or substance as a commercial insecticide is dependent upon a satisfactory relation between these two factors. The effect of insecticides on the quality and quantity of the fruit is therefore a problem of physiological importance, and in understanding of this influence plays its rôle in the economic return to the producer.

The continued use of hydrocarbon oils (of a more or less nonvolatile type) and of HCN as insecticides for citrus trees has clearly demonstrated the need for investigating their effect on the quality of the fruit as shown by the chemical composition of the juice. Since information on this subject is of interest both to the plant physiologist and to the entomologist, and no extensive investigations have been reported in the literature for the citrus-growing region of southern California, a study of the problem was undertaken as a joint project of the Divisions of Plant Physiology and Entomology of the University of California Citrus Experiment Station.

OIL SPRAY AND METABOLIC CHANGES IN PLANT TISSUES.—It is well known that hydrocarbon oils used on plants as an insecticidal spray readily penetrate the tissues. The chemical reactions of the oil after it has entered the tissue and its effect on the protoplasm has not, however, been accurately determined. The belief has prevailed that since the spray oils are highly unsulfonatable, they remain relatively inert chemically in the tissues. Further data are particularly needed on this point before any conclusions can be drawn.

Studies on the response of plants to the

[1] Paper no. 444, University of California Citrus Experiment Station, Riverside, California.

application of oil sprays (Knight *et al.* 1929, Bartholomew 1936) have shown that the oil produces in the tissues changes in respiration and in transpiration, as well as other changes which will not be mentioned here.

Knight, *et al.* noted a sharp decrease in transpiration and a rapid rise in respiration of citrus foliage when oil sprays were applied. Merrin (1929) has shown that oil sprays decreased the transpiration rate of citrus temporarily, and Bartholomew (1936) has reported that the rate of transpiration of oil-sprayed trees may, after a period of from one to eight weeks, actually exceed the rate previous to spraying. These temporary changes in the metabolism of oil-sprayed trees are not sufficient, however, to account for changes in fruit production (Woglum 1930) and in chemical composition of the fruits.

In 1927 and 1928, Higby *et al.*,[2] in California, did some experimental work to determine the effects of oil spray on the quality of Valencia orange fruits. Heavy oils were used on the trees in the experimental grove in both years, but fruits from commercially sprayed groves in which rather high concentrations of light and medium oils had been used were also tested. It was found that there was, in most cases, a reduction in total soluble solids and acids in the juice of the treated fruits and that the taste of the juice was, as a rule, impaired.

Yothers & McBride (1929) investigated the effect of oil sprays on the rate of change of the total soluble solids and the titratable acidity of Florida citrus fruits. Nearly fifty oils of various degrees of viscosity and of various percentages of unsulfonatable residue were used in these sprays. Although a reduction in the soluble solids occurred within three weeks after the oil was applied, the rate of increase of these constituents in the sprayed and unsprayed fruits was about equal during the remainder of the season. This means that the initial loss in soluble constituents by the oil-sprayed fruits was never regained. Only a small difference occurred in the soluble solids of fruits from plots sprayed with 1 and 2 per cent oil.

Ohsaki & Hayano (1931), in studying the effect of oil sprays on the quality of the Satsuma orange, have shown that the use of an oil emulsion resulted in larger fruits and a reduced rate of maturation. The oil used in the emulsions of these experiments, was classed as "C machine oil." The concentration of sugars and the density of the juice was lower in fruits from the sprayed trees than in those from the unsprayed trees, but the oil spray produced no marked changes in the titratable acidity (free acid). The oil-sprayed trees produced fruit of inferior quality, as demonstrated by the flatness of taste (due to low density of juice), the reduction in weight of fruit, and, also, a reduction in quantity of juice. Fruits with these characteristics were claimed by the authors to possess poor keeping quality.

When oil sprays were first extensively used on citrus trees they contained a high amount of sulfonatable material, whereas the oils used today are much lighter and purer. During the past several years, considerable progress has been made in the standardization of spray oils, and the present trend is toward the use of lighter oils in sprays that are to be used for insect pests on citrus trees.

FUMIGATION AND METABOLIC CHANGES IN PLANT TISSUES.—When plants are fumigated with HCN, definite physical and chemical changes occur in the tissues. Some of these factors have been investigated very thoroughly for citrus.

Bartholomew *et al.* (1941) have shown that HCN penetrates the tissues during the fumigation of citrus trees. Their experimental results also show that citrus leaves and fruits fix or change the HCN molecule to such an extent that it is not determinable by the usual methods for HCN. Much of the HCN that was absorbed by the tissues during fumigation could be recovered as HCN, but sufficient experimental evidence was obtained to show that part of the HCN that penetrates the tissues reacts chemically with the protoplasm.

It has been observed that HCN may stimulate the growth of plants. Moore (1919) states that "the after effect of fumigation is a stimulation to growth. In experiments where perfectly healthy tomato plants were grown beside plants severely injured by fumigation, the injured plants grew more rapidly and produced earlier fruit and more fruit than the

[2] Higby, Ralph H., *et al.* 1928. A study of the effect of various oil sprays on the development and composition of Valencia oranges. Unpublished data, 2(File 17): 10–99. California Fruit Growers' Exchange Research Department, Ontario, California.

healthy plants which had never been fumigated." Although no quantitative experiments have been made, the authors have observed that a very rapid growth occurs on citrus for a short period after a fumigation. This is especially noticeable if the HCN caused severe injury to the last cycle of growth.

Ebeling (1936) has shown that the leafing and fruiting cycles of lemon trees are markedly affected by the time of year of fumigation. For example, March-fumigated plots might have a greater production at a given period the following year than August-fumigated plots, but at another period of the year the reverse would be true, that is, the August-fumigated plots would have the greater production. During a period of four years, the March-fumigated and August-fumigated plots averaged about the same in production; thus the time of year of fumigation affected the fruiting cycle but not the total production over an extended period.

Since HCN reacts chemically with plant tissues, it undoubtedly has some more or less lasting effect on the tree and may affect the quality of fruit produced.

EXPERIMENTAL PROCEDURE.—Analyses were made of samples of juice of mature Valencia and Washington Navel oranges from plots located in widely separated areas in the citrus-growing region of southern California. In order that many soil types and different climatic conditions might be represented in the experiments, ten groves in the coastal, intermediate, and inland areas were selected for treatment. The number of trees in the different plots ranged from 25 to 200. Some of the plots have received the differential treatment of oil spray and fumigation since 1935; others have been treated for a much shorter period. One grove was divided into four plots of 25 trees each, and fruit samples were taken twice during the year from each of the plots previous to the oil-spray and fumigation treatments.

Analyses were also made on fruit samples from trees treated with spray which contained toxicants with the oil. The relative effect of the oil was determined by comparing results from these trees with those from control trees sprayed with the toxicants without the oil.

Oils used in sprays in these experiments were light-medium oils of 70° viscosity Saybolt at 100°F, 92 per cent unsulfonatable residue, and a distillation range of 50 to 65 per cent at 636° F. The concentrations of oils used ranged from 0.25 to 1.75 per cent.

Data from a few plots which served as controls and which received no oil spray or fumigation treatments are reported. These plots were maintained for only one season, since, for the benefit of the grove, it was inadvisable to delay longer spraying or fumigating for pest control.

The fumigation of the plots was performed by regular commercial fumigators using dosages ranging from 16 to 23 cc. per unit.[3]

The number of fruits in each sample ranged from 72 to 200. Juice was extracted from the fruits with a hand reamer.

METHODS OF ANALYSIS.—Total soluble solids were determined with an Abbé refractometer. Total acidity, expressed as citric acid, was determined by titrating an aliquot portion of the juice with a standard solution of NaOH with phenolphthalein as an indicator. The pH values were determined with a Beckman glass electrode pH meter.

Sugar determinations were made by the Hagedorn & Jensen (1923 *a* and *b*) method as modified by Blish (1933, 1934). The strength of the reagents employed by Blish was satisfactory for determining the reducing and total sugars as glucose when the values ranged from 3 to 10 mg. in 10 ml. of citrus juice. The samples were diluted when necessary, so that the values fell within this range. This method was used because comparative tests showed that it was more rapid than the best of the copper reduction methods and at the same time gave accurate results for the quantity of sugar in the sample. The factor for the reagents was determined with a sample of glucose furnished by the National Bureau of Standards.

EXPERIMENTAL RESULTS.—The results of the chemical analyses of the fruit samples from the various oil-sprayed and fumigated plots are recorded in table 1. The data are so arranged that results of tests of sprayed fruit can easily be compared with those of fumigated or untreated fruit from the same grove, sampled at the same time. Since each grove represents a different experiment in a different location, a brief description of

[3] A unit in citrus fumigation is approximately 100 cubic feet for the average-sized citrus tree.

the experiment and of the results in each grove follows.

Coastal Area.—In the coastal area, only Valencia orange groves were selected for experimental purposes. An inspection of the data (Table 1) from groves 1, 2, and 3 of this area show some very striking differences in the composition of the juice of fruit samples from the oil-sprayed and from the fumigated plots. Plots 1 and 2 of grove 1 have received their respective oil-spray and fumigation treatments annually since 1936. The last treatment, before sampling, was applied from August 26 to 29, 1938. The fruit samples were picked on August 15, 1939. It can be readily observed that the percentages of soluble solids and of reducing and total sugars are markedly less in the oil-sprayed fruit.

Each of the two plots in grove 2 contained 28 trees, and the oil spray and fumigation treatments had been applied

Table 1.—Comparative analyses of juice of Valencia and Washington Naval oranges from sprayed, fumigated, and untreated trees located in different areas in southern California, 1938–1941.

Location of Trees	Spray and Fumigation Treatment of Trees	Date of Treatment	Date of Sampling	Analysis of Juice Samples[1]					Ratio, Soluble Solids to Acid
				Soluble Solids, Per cent	pH Value	Citric Acid, Per cent	Reducing Sugars, Per cent	Total Sugars, Per cent	
Valencias (Coastal Area)									
Grove 1:									
Plot 1	Light-medium emulsive oil, 1.67%	8-29-38	8-15-39	13.16	3.51	1.11	5.36	10.11	11.86
Plot 2	HCN, 18-cc. schedule	8-26-38	8-15-39	14.49	3.42	1.28	6.13	11.03	11.32
Grove 2:									
Plot 1	Light-medium emulsive oil, 1.67%	10-16-38	4-25-39	9.70	3.51	1.09	2.85	6.80	8.90
Plot 2	HCN, 20-cc. schedule	1-27-39	4-25-39	11.47	3.43	1.29	3.39	7.81	8.90
Plot 1	Light-medium emulsive oil, 1.67%	10-16-38	10- 3-39	11.68	3.80	0.99	4.22	8.44	11.80
Plot 2	HCN, 20-cc. schedule	1-27-39	10- 3-39	12.60	3.75	1.02	4.77	9.46	12.35
Plot 1	Light-medium emulsive oil, 1.67%	10-16-39	5- 3-40	9.76	3.42	0.89	3.14	7.59	10.97
Plot 2	HCN, 20-cc. schedule	2-15-40	5- 3-40	11.37	3.26	1.22	3.96	9.06	9.32
Plot 1	Light-medium emulsive oil, 1.67%	10-16-39	9-16-40	10.91	3.80	0.81	3.82	7.86	13.47
Plot 2	HCN, 20-cc. schedule	2-15-40	9-16-40	12.57	3.75	0.91	4.90	9.76	13.81
Plot 1	Light-medium emulsive oil, 1.75%	10-14-40	4-23-41	10.42	3.34	1.03	3.18	7.57	10.12
Plot 2	HCN, 22-cc. schedule	2- 3-41	4-23-41	12.71	3.13	1.52	4.32	9.31	8.36
Grove 3:									
Plot 1	Light-medium emulsive oil, 1.75%	11-10-38	9- 5-39	10.55	3.62	0.85	3.07	7.42	12.42
Plot 2	HCN, 16-cc. schedule	8-27-38	9- 5-39	11.75	3.60	0.83	4.05	8.67	14.16
Washington Navels (Intermediate Area)									
Grove 4:									
Plot 1[2]	Light-medium emulsive oil, 1.67%	10-13-39	1-29-40	10.76	3.29	1.05	3.73	7.72	10.25
Plot 2[2]	Miscible oil, 1.33%, plus lime-sulfur, 1.33%	10-13-39	1-29-40	10.95	3.29	1.09	3.58	7.80	10.05
Plot 3	Light-medium emulsive oil, 1.67%; walnut-shell flour, 3 pounds per 100 gallons	10-13-39	1-29-40	10.59	3.40	0.97	3.65	7.87	10.92
Plot 4	HCN, 18-cc. schedule	8-19-39	1-29-40	11.90	3.38	1.13	3.92	8.96	10.53
Grove 5:[3]									
Plot 1	Light-medium emulsive oil, 0.25% K-58[4] plus 11.75% derris extract, 0.0625%	11- 2-39	2- 6-40	11.66	3.45	0.90	4.45	9.16	12.96
Plot 2[2]	Light-medium emulsive oil, 1.67%	11- 2-39	2- 6-40	10.90	3.43	0.91	4.08	8.58	11.98
Plot 3[2]	Light-medium emulsive oil (1.5% g. m. o.[5]), 0.25%; dibutylphthalate plus 5.87% derris extract, 0.125%	11- 2-39	2- 6-40	11.55	3.39	0.95	4.26	8.63	12.16
Plot 4	HCN, 18-cc. schedule	10-24-39	2- 6-40	11.91	3.44	0.95	4.33	9.53	12.54
Grove 6:									
Plot 1	Medium emulsive oil, 1.67%	11-22-40	3- 5-41	12.31	3.32	1.05	3.79	8.65	11.73
Plot 2	Light-medium emulsive oil, 1.67%	11- 6-40	3- 5-41	12.91	3.34	1.08	4.51	9.08	11.95
Plot 3	Check (no treatment)	—	3- 5-41	14.23	3.40	0.97	5.16	10.31	14.67
Grove 7:									
Plot 1	Light-medium oil, 1.67%	10- 9-40	3-10-41	11.37	3.44	0.89	4.04	8.75	12.78
Plot 2	Light-medium emulsive oil (1.75% g. m. o.[5]), 0.5%; *Cardolite* with 11% derris extract, 0.125%	10- 9-40	3-10-41	12.31	3.42	0.90	4.44	9.89	13.68
Plot 3	Light-medium oil, 0.5%; K-58[4] plus 8.8% derris extract, 0.34%	10- 9-40	3-10-41	12.63	3.39	1.03	4.65	9.98	12.26
Plot 4	Light-medium oil, 0.5% K-58[4] cube root slurry mix,[6] 2 pounds per 100 gallons	10- 9-40	3-10-41	12.23	3.47	0.97	4.25	9.17	12.61
Plot 5	No oil; DN,[7] 0.05%, in solution as triethanolamine salt; wetting agent, 2 ounces per 100 gallons	10- 9-40	3-10-41	12.91	3.37	1.14	4.84	10.23	11.32

Table 1 (Continued)

Location of Trees	Spray and Fumigation Treatment of Trees	Date of Treatment	Date of Sampling	Analysis of Juice Samples[1] Soluble Solids, Per cent	pH Value	Citric Acid, Per cent	Reducing Sugars, Per cent	Total Sugars, Per cent	Ratio, Soluble Solids to Acid
Valencias and Washington Navels (Inland Area)									
Grove 8 (Valencias):									
Plot 1	No treatment	—	3-21-39	10.74	3.31	1.67	2.65	6.88	6.43
Plot 2	No treatment	—	3-21-39	10.81	3.29	1.79	2.64	6.92	6.05
Plot 3	No treatment	—	3-21-39	10.67	3.34	1.52	2.59	7.05	7.03
Plot 4	No treatment	—	3-21-39	11.20	3.34	1.58	2.70	7.21	7.09
Plot 1	No treatment	—	8-29-39	11.77	3.68	1.08	3.84	8.06	10.90
Plot 2	No treatment	—	8-29-39	11.58	3.68	1.09	3.92	7.81	10.62
Plot 3	No treatment	—	8-29-39	11.26	3.69	1.05	3.90	7.85	10.72
Plot 4	No treatment	—	8-29-39	12.06	3.63	1.08	4.14	8.03	11.17
Plot 1	HCN, 23-cc. schedule	2-11-40	4-10-40	11.17	3.35	1.24	3.06	7.93	9.01
Plot 2	Light-medium emulsive oil, 1.5%	10-19-39	4-10-40	9.16	3.40	1.11	2.40	6.24	8.25
Plot 3	HCN, 23-cc. schedule	2-11-40	4-10-40	10.83	3.43	1.15	2.87	7.49	9.42
Plot 4	Light-medium emulsive oil, 1.5%	10-19-39	4-10-40	9.96	3.46	1.07	2.54	6.68	9.31
Plot 1	HCN, 23-cc. schedule	2-11-40	9-12-40	11.83	3.80	0.80	4.22	8.28	14.79
Plot 2	Light-medium emulsive oil, 1.5%	10-19-39	9-12-40	8.76	3.90	0.73	2.90	6.14	12.00
Plot 3	HCN, 23-cc. schedule	2-11-40	9-12-40	11.11	3.95	0.79	4.00	7.86	14.06
Plot 4	Light-medium emulsive oil, 1.5%	10-19-39	9-12-40	9.90	4.00	0.71	3.19	6.38	13.94
Plot 1	HCN, 23-cc. schedule	8-15-40	4-14-41	11.17	3.22	1.19	2.87	8.11	9.39
Plot 2	Light-medium emulsive oil, 1.75%	10- 1-40	4-14-41	10.22	3.33	1.17	2.46	7.28	8.74
Plot 3	HCN, 23-cc. schedule	8-15-40	4-14-41	11.03	3.38	1.19	2.72	7.81	9.27
Plot 4	Light-medium emulsive oil, 1.75%	10- 1-40	4-14-41	10.57	3.40	1.15	2.60	7.34	9.19
Grove 9 (Navels):									
Plot 1	Light-medium emulsive oil, 1%, plus ground derris root, 4 pounds per 100 gallons	8-23-39	2- 7-40	11.48	3.50	0.83	4.30	9.58	13.83
Plot 2	Light-medium tank-mix oil, 1.5%	8-23-39	2- 7-40	11.48	3.50	0.83	4.30	9.35	13.83
Plot 3	Light-medium oil emulsion, 1.67%	8-23-39	2- 7-40	11.55	3.45	0.83	4.37	8.82	13.92
Plot 4	Light-medium emulsive oil, 1.5%	8-23-39	2- 7-40	11.49	3.50	0.86	4.49	9.20	13.36
Plot 5	HCN, 18-cc. schedule	9- 2-39	2- 7-40	12.59	3.48	0.90	4.69	11.04	13.99
Plot 6	HCN, 18-cc. schedule	1-10-40	2- 7-40	12.53	3.50	0.88	4.73	10.81	14.24
Plot 7	Check (no treatment)	—	2- 7-40	12.58	3.45	0.90	4.88	10.81	13.98
Grove 10 (Navels):									
Plot 1	Light-medium emulsive oil, 1.5%	8-25-39	2- 8-40	11.42	3.35	1.00	4.11	9.20	11.42
Plot 2	Light-medium oil emulsion, 1.67%	8-25-39	2- 8-40	11.42	3.35	1.00	4.19	8.90	11.42
Plot 3	Light-medium tank-mix oil, 1.5%	8-25-39	2- 8-40	11.63	3.35	1.00	4.30	8.97	11.63
Plot 4	Light-medium emulsive oil, 0.75%, plus ground derris root, .75 pound per 100 gallons	8-25-39	2- 8-40	11.44	3.35	1.00	4.07	9.28	11.44
Plot 5	HCN, 18-cc. schedule	8-24-39	2- 8-40	12.60	3.30	1.00	4.62	9.76	12.60

[1] Each sample contained from 72 to 200 fruits selected at random. Juice was extracted with a hand reamer.
[2] Represents three replicate plots; values reported are the mean of values determined on samples from these plots.
[3] Represents two replicate plots; values reported are the mean of values determined on samples from these plots.
[4] K-58 = 2(4-tertiary butylphenoxy) ethanol.
[5] g. m. o. = glyceryl monooleate.
[6] See Boyce *et al.* (1940).
[7] *DN* = 2,4-dinitrocyclohexylphenol.

annually since 1935. Chemical analyses of the fruit samples were made for the seasons of 1939, 1940, and 1941. Fruit samples were collected twice each year from each plot, once early in the season (April or May) and once late in the season (September or October), except in 1941. Determinations of the composition of the juice of the fruit at these two periods demonstrated clearly that the differences produced in fruit by the oil spray not only existed early in the season, when the fruit had barely reached the maturity test, but persisted during the entire ripening period of the fruit.

Grove 3 had received the differential treatments for one year only. The trees in this grove were about 30 years old, and samples were collected from 35 trees in each plot. This experiment is of interest in that the difference in chemical composition of the fruit was shown the first year after the application of the treatments.

Intermediate Area.—The next series of experiments were carried out on plots in groves 4, 5, 6, and 7, located in an area

between the coastal and inland areas of the citrus-growing region of southern California. In this intermediate area, only Washington Navel orange groves were selected for experimental purposes. Most of the oil sprays used in these experiments contained toxicants.

All the plots in grove 4 were treated for one year only. Plots 1 and 2 had three replicates each, and the values reported in table 1 are the mean of the analytical values determined on samples from the three replicates. There were 52 trees in each of the four plots, but after the assignment of guard rows, there remained only 25 trees for sampling. The oil-sprayed plots in this group were treated with a light-medium oil of 1.33 to 1.67 per cent concentration. As might be expected, the juice of the fruit samples from the oil-sprayed plots contained less soluble solids and less reducing and total sugars than that of fruits from the fumigated plots.

Of significance is the low concentration (0.25 per cent) of oil in the spray used on plots 1 and 3 of grove 5. The juice samples from these plots contained slightly less soluble solids, less reducing sugars (with one exception), and less total sugars than those from the fumigated plot. The fruit from plot 2, which received the 1.67 per cent oil spray, showed markedly less soluble constituents than fruit from the fumigated plot. The trees in this grove were about 20 years old, and the soil was a gravel loam type. The treatment was applied for one year only.

Grove 6 is of special interest in that the juice of fruit from the oil-sprayed plots can be compared with that from a plot which had received no treatment (Table 1). The differences in chemical composition of these samples were of the same order of magnitude as those shown between samples from oil-sprayed and fumigated plots in other groves (Table 1).

Except in plot 1, the trees in the plots of grove 7 were treated with sprays containing other insecticidal substances. The spray used on trees in plot 1 contained 1.67 per cent oil, while that used in plots 2, 3, and 4 contained only 0.5 per cent oil, and that used in plot 5 contained only toxicants. None of these trees had been fumigated for two years. When the results are compared, it can be seen that in spite of the toxicants in the spray, fruits from plot 1, which received the highest percentage of oil, contained the lowest percentage of soluble solids, and of reducing and total sugars; and the fruits from plot 5, which received no oil, contained the highest amount of soluble constituents. The fruit from the plots in which the lowest concentrations of oil were applied also had slightly less soluble constituents than those receiving no oil.

INLAND AREA.—The data which are recorded for groves 8, 9, and 10 (Table 1) were obtained from experimental plots located in the inland area. Fruit samples from the plots of grove 8 (Valencias) have been collected and analyzed since 1939, but insecticidal treatments were not begun until 1940. The plots of grove 9 (Washington Navels) have been sprayed or fumigated annually since 1935, and the plots of grove 10 (Washington Navels) have received the differential treatments since 1936, but the composition of the fruits from these two groves was determined for the year 1940 only.

The composition of the fruit samples from the plots of grove 8 was determined both early in the season (March 21) and late in the season (August 29) in 1939, the year in which no treatment was applied. The composition of the samples on these dates (Table 1) shows the uniformity in the fruit of the plots at the time of sampling. Samples taken from the same plots the following year (1940), after the oil-spray and fumigation treatments had been applied, show the effect of the oil in reducing the soluble constituents of the juice. At the time of writing, only the data for the early sampling for 1941 had been determined and recorded (Table 1), but the experiments in this grove are being continued.

The distinctive feature of grove 9 is the differential treatment of the plots: plots 1, 2, 3, and 4 were sprayed with oil; plot 5 was fumigated in the fall (September 2, 1939); plot 6 was fumigated in the winter (January 10, 1940); and plot 7, which served as a control, received no treatment. A striking similarity may be noted in the composition of the fruit samples from the three last-named plots (Table 1). It appears from these results that the fumigation of citrus trees, either in the fall or in the winter, has no marked effect on the composition of the soluble constituents of the juice of the mature fruits. When the composition of the fruits from any one of

these three plots is compared with that of fruits from oil-sprayed plots, the characteristic reduction of the soluble substances by the oil is apparent.

In grove 10, the amount of oil applied to the trees in the four oil-sprayed plots varied from 0.75 to 1.67 per cent. The fumigated plot (Plot 5) was treated in late summer. The comparative analyses of the fruit samples from the five plots (Table 1) show a lower concentration of soluble substances in the juice from all the oil-sprayed samples.

It can be said, therefore, that there was a reduction in the soluble constituents of the juice of fruits in all the plots that were sprayed with oil. The components chiefly affected were the total soluble solids and the reducing and total sugars. The percentages of reduction of these constituents for the different groves are shown in figure 1. The data from fumigated plots in some groves and from nonfumigated or untreated plots in others, were used as bases for calculating the percentages of reduction. In these calculations only the data from plots sprayed with 0.75 to 1.75 per cent oil were used. Since the numerical values for calculating the percentages were different for each grove and samples of fruit from widely separated areas differed in chemical composition, values for the different groves varied greatly.

The effect of oil spray was not so decisive on the titratable acidity of the juice (expressed as citric acid) as on the other constituents. In grove 10, there was no change in titratable acidity as a result of the different treatments; in groves 1, 2, 4, 5, 7, 8, and 9, there was a decrease; and in groves 3 and 6, a slight increase. The percentages of decrease or increase in citric acid were not recorded in figure 1, for with low total concentrations of acid, a small variation caused excessively high values. No marked differences were observed in the pH of the juice from various samples. As orange juice is highly buffered, these small changes in titratable acidity would alter the pH values very slightly.

DISCUSSION.—The data in table 1 were obtained from groves distributed over a large area. As citrus is grown in southern California in areas of different climatic and soil conditions, it was essential to have the experimental plots located in commercial groves typical of these conditions. The coastal and inland regions differ greatly in temperature and humidity. These factors alone are sufficient to cause changes in the rate of ripening of the fruit, but more important is the effect of humidity and temperature on the evaporation of the oil from the surface of the

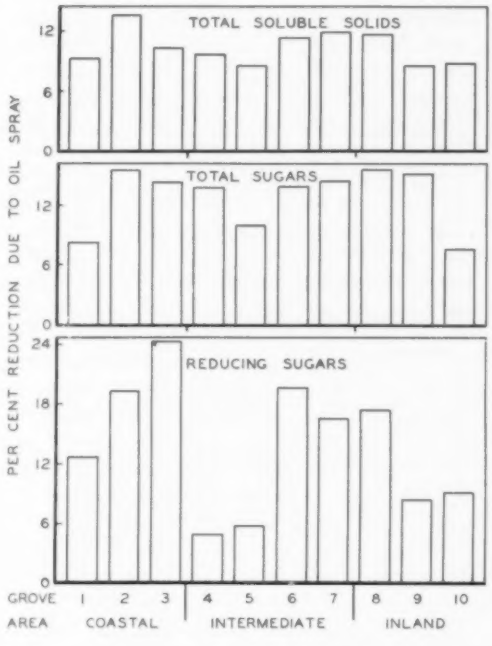

FIG. 1.—Histograms showing the percentage decrease of total soluble solids and of total and reducing sugars in oil-sprayed fruit, the percentages being calculated on the basis of the percentages of these constituents in the fumigated or untreated fruit for each grove in the coastal, intermediate, and inland areas. Fruit samples were taken from trees sprayed with 0.75 to 1.75 per cent light-medium oil.

tissues. Nevertheless, under these environmental variations, sufficient oil penetrated the tissues to produce a change in the composition of the fruit. This is evidenced by the fact that the fruit samples from the oil-sprayed plots showed a lower concentration of soluble substances than those from the fumigated and untreated plots, irrespective of the area from which the samples were collected.

In comparing the authors' results with those of other investigators, it should be remembered that in the present investigations, light-medium oils were used. Although the relation between the weight of oil and its effect on the chemical composition of citrus fruits has not been accu-

rately determined, it has been learned from practical experience that heavy oils have a more pronounced physiological effect than the light oils. Light volatile oils in sprays apparently have little or no effect on the chemical composition of the fruit. This statement is based on preliminary experiments only, in which the authors noted that the soluble constituents in the juice of fruit samples from trees sprayed with kerosene, in concentrations as high as 10 per cent, were not significantly different from the soluble constituents of fruit from control and fumigated trees. These experiments are being continued and expanded.

As the amount of oil deposited on the leaves by the spray was not determined, an exact relationship between the amount of oil deposited on the tree by the spray and the reduction of soluble constituents in the juice cannot be shown. The amount of reduction of soluble substances is related primarily to the deposit of oil on the tissues and secondarily to the concentration of oil in the spray at the time of application. Although oil deposit is affected by the type of spreader and the concentration of electrolytes in the spray, yet under a given condition, the oil deposit (Ebeling 1941) bears a direct relation to the concentration of oil in the spray. The ideal condition for a study of the relation between oil deposit and composition of the fruit would be one in which the same oil deposit was obtained repeatedly with a given concentration of oil in the spray. Under conditions of commercial operations, variations in oil deposit undoubtedly occur with sprays bearing the same oil concentration. These conditions are covered in the experiments reported in this paper since the goves were widely separated and were sprayed by different operators.

Although many factors may affect oil deposit, there was no marked difference in soluble solids in fruit samples from plots sprayed with 1 and 1.75 per cent light-medium oils. This is in agreement with the results of Yothers & McBride (1929), who showed that juice of fruit samples from plots which had been sprayed with 1 or 2 per cent oil gave practically the same reading with a *Brix* hydrometer. From the results reported in table 1 (Groves 5 and 7), it is evident that a slight reduction in soluble constituents was produced with as low as 0.25 and 0.5 per cent oil spray. It appears, then, that a 1 per cent oil spray produced a physiological effect of such intensity that a 1.75 per cent oil spray failed to cause further changes in the chemical composition of the fruit.

The time of the year in which oil spray is applied to citrus trees may have its effect on the composition of the fruit, but there is not a direct relation between this time and the amount of reduction of the soluble constituents in the juice. Samples of fruit collected from trees in grove 1 approximately twelve months after spraying, showed a reduction in soluble solids and in reducing and total sugars of 9.18, 12.56, and 8.34 per cent, respectively; and samples collected from trees in grove 6 approximately four months after spraying, showed reductions of 11.39, 19.58, and 14.02 per cent. Although the results are not reported in this paper, a reduction of 7.00 per cent of the soluble constituents has been obtained from fruit samples two months after the application of oil spray.

The rind of mature fruits from oil-sprayed trees was usually much greener in color than that of fruits from the unsprayed or fumigated trees. Exceptions to this rule did occur, however. In many instances the rind of fruit from oil-sprayed and fumigated trees possessed the same intensity of color, but the soluble constituents of the juice were lower in the oil-sprayed fruit.

SUMMARY.—The spraying of citrus trees with light-medium oils in concentrations of 0.25 to 1.75 per cent caused a reduction in the total soluble solids and in reducing and total sugars of the fruit juice. Oil sprays with and without the toxicants were equally effective in reducing the soluble constituents in the fruit. Although oil spray had a tendency to reduce the titratable acidity, the results were not so decisive as in the case of the other soluble constituents. Since orange juice is highly buffered, the small change in titratable acidity of the juice was not sufficient to produce an effective change in pH of the mature fruit. Only slight differences occurred in the composition of the juice of fruits from plots that had been sprayed with 0.75 to 1.75 per cent oil. The data show that although the groves of these experiments were widely separated and differed greatly as to en-

vironmental conditions and soil types, the change effected by the spray in chemical composition of the fruit was practically the same. The time of the year at which the oil was applied was found to be relatively unimportant. The fumigation of citrus trees with HCN either in the fall or in the winter, had no marked effect on the chemical composition of the mature fruit.—9-2-41.

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Materials Added to Oil Spray to Increase Its Effectiveness in Citrus Pest Control[1]

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It is in a study of the limitations of spray oils as insecticides that the manner and extent of their improvement by means of toxicants is most clearly revealed. The very factor that has made oil suitable for use on citrus trees, namely, the removal of the phytocidal unsaturated hydrocarbons, has greatly reduced its effectiveness against the majority of insects. Consequently the lethal effect of oil must be accounted for mainly by its ability to suffocate the insect (de Ong & Chamberlin 1927) or, failing this, to gradually bring about death in some such manner as the "prolonged impairment of physiological processes" suggested by Smith (1932); or the oil may be effective as a residue which may prevent the development of newly hatched or newly born larvae as noted by Woglum (1926), Woglum & La Follette (1934) and others. The writer (Ebeling 1936) has noted a prolonged impairment of the reproductive function of the red scale, which is another example of more or less obscure phenomena which affect to a greater or less extent the final results of an oil spray.

The relative chemical inertness of spray oil would not reduce its insecticidal effectiveness if a sufficient amount could be used to insure in all cases a penetration and occlusion of the spiracles and tracheae, which would result in suffocation in all cases except possibly with light oils such as kerosene, which has been observed

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to be expelled from the tracheae of red scales (de Ong *et al.* 1927). If death invariably resulted from suffocation, chemical toxicity would be superfluous as a means of killing the insect. It is because of the fact that suffocation by oil can not always be effected because of the limitation in the amount of oil the tree will tolerate or because of the rapid absorption of the oil by certain types of tree surface (Ebeling 1936), or because of the inability of the oil to reach the insect spiracles for any of a number of reasons, that the more obscure and secondary effects, or, let us say, "physiological effects" of the oil are of importance. It is in this field of somewhat vague and indefinable "physiological effects" that toxicants which are added to oil are assumed to have their place.

An example of the possible rôle of toxicants as an auxiliary to the insecticidal effects of spray oil is afforded by the red scale. The writer (Ebeling 1936) has considered the various means by which spray oil kills the various stages of the red scale. In the case of the adult insect, death may result from suffocation if the oil reaches and penetrates the spiracles. The scales, even though completely suffocated, may live as long as 72 hours after being immersed *in situ* in heavy spray oil. In an oxygen-free atmosphere they have been observed to survive for as long as 26 hours (Ebeling 1936). Death from oil spray may occur throughout a period of a month or more after treatment. When the scales are situated on the porous bark, the oil film deposited by the spray usually penetrates the bark so quickly that an insufficient quantity is drawn under and into the body of the scale and in such cases the period required for death of the scale is greatly prolonged. The oil may reach only one or two spiracles or perhaps none, but nevertheless probably penetrates under the scale armor, especially in the region of the pygidium, and enters the scale body in limited quantities. Such small quantities of oil may eventually result in death, but too often do not. Often the oil results merely in a reduction in the rate of emergence of young or in the production of a varying percentage of dead or premature young. It is reasonable to assume that in circumstances under which the oil does not reach the spiracles the delayed and uncertain effects of the oil might be changed to rapid and positive effects by the addition of a toxicant of known scalicidal value. This assumption has been borne out by the results which have been achieved by the incorporation of toxicants into oil sprays.

Materials added to oil spray to increase its effectiveness against citrus pests may be divided into two groups: those whose effect is mainly physical, affecting the oil deposition or distribution on the plant surface or the penetration of the oil into plant and insect tissue, and those whose effect is chemical, including the true toxicants. It is realized, of course, that the boundaries between physical and chemical effects may sometimes be vague and that a material might act both physically and chemically in the improvement of an oil spray. The classification must therefore be somewhat arbitrary.

MATERIALS INCREASING THE EFFECTIVENESS OF OIL SPRAY BY PHYSICAL MEANS. *Emulsifiers and Spreaders.*—A detailed discussion of this subject would be too vast to be properly treated in this paper. The writer wishes merely to emphasize the function of emulsifiers and spreaders, regardless of their composition, which is mainly to insure a uniform distribution of the oil globules in the spray tank and the optimum deposit of oil on the tree and insect surfaces compatible with adequate distribution and uniformity of the oil film. Thus an emulsifier must not produce too "tight" an emulsion, resulting in inadequate oil deposit, but must on the other hand not allow for stratification of the oil in the spray tank. The latter consideration is of increasingly less importance as the agitation in the spray tank is increased in speed and efficiency, resulting in the case of modern power sprayers in a uniform mechanical mixture of oil and water alone without the aid of an emulsifier. The spreading of the spray must be sufficient to result in a reasonably uniform distribution of the oil over the tree surface, but must not cause excessive "run off" of the oil. The variability in the performance of emulsifiers in different types of water, and possibly as affected by other factors, is an important consideration. The addition of a toxicant may also affect either favorably or adversely the performance of an emulsifier or a spreader. Likewise an unsuitable emulsifier or spreader may cancel the effects of the toxicant by resulting in in-

adequate deposit or distribution of the toxic oil. Consequently if a toxic oil spray is to be compared for insecticidal effectiveness with a straight oil spray, the amount and distribution of oil should be taken into consideration. Insecticidal effect per unit of oil deposited should be the basis of comparison of oil sprays.

Finely Divided Solids.—The writer (Ebeling 1940) has demonstrated the manner in which the addition of finely divided solids preferentially wet by the oil, such as walnut shell flour (200 mesh) may improve the distribution of oil over a plant surface and enhance plant surface capillarity, by which means a sessile insect may draw oil to its body from a considerable distance. Solids may also increase oil deposit, or may act as a governor, increasing deposit in waters which tend toward light oil deposit and decreasing deposit in waters which tend toward high deposit and rapid and uneven "build up" of oil, as the writer has found to be the case with zinc oxide added to toxic kerosene emulsions. No sensational developments have resulted from the addition of finely divided solids to spray oil, but it appears to the writer that results have been sufficiently encouraging to warrant further research on this subject.

Emulsive Oils.—Knight (1934) introduced into commercial practice the quick-breaking emulsive type of spray oils in which the emulsifier and sometimes additional solutes are dissolved in the oil. These solutes may profoundly affect physical properties of the oil such as viscosity (or gelatinization), interfacial tension oil/water, penetrability into plant tissue and preferential wetting of solids which might be added to the oil. The emulsive oils have the advantage of containing the emulsifier within the oil, thus obviating the necessity of emulsification before introducing the oil into the spray tank.

Another innovation brought about by the emulsive oils is penetration control, a factor which may assume an increasingly greater importance in oil spray research as lighter oils come into prominence in citrus spraying. The writer has found that kerosene, for instance, may be prevented from penetrating the lower surface of a citrus leaf, where penetration of oil is ordinarily very rapid, until the kerosene has left the surface of the foliage by evaporation. This can be accomplished by the addition of only 0.06 per cent of a salt of a higher fatty acid[1] to the kerosene.

This solute also results in an increase in the viscosity of the kerosene and an apparent gelatinization, causing the kerosene to flow from a pipette with partially occluded aperture in a thin stream, not readily broken, rather than in the succession of drops which is normal for straight kerosene. Kerosene with 0.12 per cent of the solute mentioned above flows through the usual 10 ml. pipette about twice as fast as light-medium spray oil (viscosity 70 seconds Saybolt at 100° F.). However, it flows through the orifice of the Saybolt viscosimeter at about the same rate as the light-medium oil. It flows through still smaller apertures more slowly than light-medium oil. It appears, therefore, that the smaller the aperture through which the kerosene plus solute flows, the greater its resistance to flow in comparison with a spray oil which has the same Saybolt viscosity. The kerosene plus solute penetrates into porous wood more slowly than heavy spray oil. In this case the capillaries are assumed to be extremely small. Apparently in order to retard the penetration of oil into porous wood, a solute must cause the oil to have the consistency described above. This phenomenon is apparently not necessary to cause retardation of penetration into foliage, although when it occurs it obviously must be a factor in retarding penetration of oil into the undersides of citrus leaves, where the stomata occur.

Apparently a gelatinization of oil may occur even with solutes not suspected of causing this phenomenon. Thus the penetration into wood of a kerosene containing 1 per cent aluminum dinaphthenate is somewhat retarded, although the Saybolt viscosity of oil is not affected by the solute.

The solutes which have been used commercially have been added to the oil at the rate of about 1 to 2 per cent. They have resulted in retardation of oil penetration mainly on the leaves, green twigs and fruit. When used against scale insects such as the black scale, *Saissetia oleae*, which are mainly confined to these portions of the tree the investigations at

[1] The writer in indebted to Mr. C. K. Hewes, Chief Chemist, Richfield Oil Company, for preparation and supply of the treated kerosene.

the Citrus Experiment Station have indicated the superiority of emulsive oils to other types of spray oils in the control of the scales. Presumably this improvement in effectiveness is due, at least in part, to the delay in penetration of the oil into the plant tissue, making the oil more available to the scales.

Aside from gelatinization, such factors as the relative number of hydroxyl radicals of solutes in the oil may affect the relative rapidity of penetration of different oils into plant tissue (Ebeling 1939).

There is no evidence that the solutes added to emulsive oils hinder the penetration of oil into the insects to such an extent as to reduce their insecticidal effectiveness. They do not impede the penetration of oil into solid beeswax or capillaries lined with beeswax (Ebeling 1939) or into tubes into which the bodies of scale insects have been pressed according to a uniform procedure. Apparently insect wax is not sufficiently polar to result in an accumulation of the somewhat polar solutes at the interface oil/insect. Likewise, any degree of gelatinization of the oil which has been encountered in experimental work is not sufficient to prevent the passage of oil beneath the bodies of scales or into their tracheae. Thus a penetration differential has been effected, making possible a retardation of penetration of oil into the substratum upon which scale insects rest, without reducing the insecticidal effectiveness of the spray.

The value of adding certain toxic compounds, such as lead arsenate and cryolite, to oil spray is greatly increased if an emulsive oil is used. The observation of Persing (1935), for instance, that cryolite is preferentially wet by emulsive oils, making possible a retention of the cryolite in the oil phase, led to a sound basis for the use of cryolite in oil in the control of orange worms, *Argyrotaenia citrana* and *Holcocera iceryaeella*. In all cases in which the cryolite remained in the oil phase there was a very heavy deposit of cryolite, excellent wetting and spreading and relatively high toxicity as compared to preparations in which straight oil was used.

A similar use for emulsive oil has been found in the preparation of internal dispersions of sulfur in oil,[1] used as an effective treatment for the citrus bud mite, *Eriophyes sheldoni*.

The use of emulsive oils has undoubtedly opened new fields of investigation. New developments in oil sprays beyond those which could be obtained with straight oil alone can be confidently expected.

MATERIALS INCREASING THE EFFECTIVENESS OF OIL SPRAY BY CHEMICAL MEANS.—Some materials that are added to oil may be directed against one pest and the oil against another. These may be used with the oil either for the sake of economy incident to the treatment of two or more pests with a single spray, or because the oil may aid in the spreading and deposition of the material, as in the case of cryolite used with oil in orange worm control. Some materials may improve an oil spray merely by the addition of their independent insecticidal value to that of the oil, even though both the oil and the added material are directed against the same pest. Other materials, especially the sulfur compounds, appear to have a marked "synergistic" effect when added to oil. Still other compounds, such as pyrethrins and rotenone, are effective toxicants themselves but when used against certain pests depend on the oil to carry them to or into the insect's body. The possibility of synergistic effect can not be ruled out in such cases, but it is probable that synergism is not of prime importance, in view of the known independent toxicity of the toxic compounds involved. Thus, for example, kerosene has little value as a spray for red scale but it has a great penetrating ability and is an excellent means of carrying rotenone into the well-protected scale bodies, after which the rotenone presumably kills by means of its independent toxicity. Likewise the eggs of greenhouse thrips, which are located beneath the epidermis of the citrus leaf, can be reached but not killed, by spray oil. The oil can be used to carry pyrethrins to the eggs, however, and the pyrethrins are then able to kill the eggs.

Space allows only a summary of developments in the field of toxicants added to oil in citrus pest control.

Oil and Cryolite.—Cryolite was first added to oil in order to effect an economy in the treatment for orange worms by combining an orange worm treatment with oil spray. The oil spray is directed

[1] Boyce, A. M., 1941. From notes on file at the Citrus Experiment Station, University of California, Riverside.

against scales and mites, and thus a single treatment for the two pests is made possible. Incidentally it was found, however, that the emulsive oil made possible a still further economy by reducing the amount of cryolite necessary per tree to control the orange worms. The oil also improved the spread and adhesiveness of the cryolite. Two pounds of cryolite to 100 gallons are added to an emulsive oil spray at the regular dosage and the spray is applied with a thoroughness necessary for the control of scale insects or the citrus red mite, *Paratetranychus citri*.

Oil with Selocide and Wettable Sulfur.—The combination of oil, *Selocide* and wettable sulfur was found to be an effective preparation for the control of the citrus red mite (Hoskins, *et al.* 1938). *Selocide* is a 30 per cent solution of potassium hydroxide, ammonium hydroxide, sulfur and selenium in the proportion corresponding to the empirical formula $(KNH_4S)_5Se$. The proportions of the ingredients comprising the spray were as follows: *Selocide*, 1 pint; wettable sulfur, 1 pound; light-medium oil[1] 0.33 gallon; sodium caseinate, 3 to 4 ounces; water, 100 gallons. After several years' use, there was no evidence of harmful effects upon citrus trees, and fruit injury occurred to only a limited extent in certain districts. Likewise it was concluded after an exhaustive study of the problem (Hoskins, *et al.* 1938) that the proper use of *Selocide* on citrus offered no hazard to public health. Nevertheless public health considerations have prevented the acceptance of this material in citrus pest control.

Oil and Sulfur Compounds.—A combination of light-medium oil at 0.33 per cent and ammonium polysulfide at 1.5 per cent, with casein spreader, has been quite generally used in spring treatments for citrus red mite and citrus bud mite in areas where the bud mite is a problem (Boyce 1940).[4] A combination of sulfur in oil in water[4] has been found to be about as effective against the bud mite, and is in addition relatively inexpensive. The preparation consists of 0.5 per cent light-medium emulsive oil plus 4 pounds of sulfur (325 mesh) and approximately 1 ounce of blood albumin stabilizer (25 per cent blood albumin) per 100 gallons of water. It is important to use the ingredients in the exact proportion recommended in order to insure an emulsion of the proper physical consistency. This mixture is hazardous in hot weather and may have to be confined to winter and early spring.

Miscible Oils and Lime-Sulfur.—Investigations by Paul R. Jones established the practice of using light miscible oils combined with lime-sulfur for the control of various pests such as the unarmored scales and the mites. The miscible oil and lime-sulfur combination has an insecticidal effect which is greater than that which could be expected from the combined independent action of its ingredients, indicating a possible synergism, such as is apparently also the case in the control of bud mite with the emulsive oil-sulfur mixture.

The latest published official recommendation for the use of miscible oil and lime-sulfur appears to be that of Woglum (1939) who recommended its use for the control of the citricola scale, *Coccus pseudomagnoliarum*, in central California. Four gallons of miscible oil, 4 gallons of lime-sulfur and 3 pounds of casein spreader per 300 gallons of spray was recommended. It was recommended that the spray be used not earlier than October, that spraying should not be done at temperatures over 90° F., and that care should be exercised to avoid spraying immediately before freezing temperatures.

In southern California miscible oil and lime-sulfur is being less extensively used than previously, mainly because of occasional severe damage to trees and fruit resulting from its use. However, a considerable acreage is still annually treated with this spray.

Oil and Nicotine.—Nicotine in oil has not been given an important place in citrus pest control, probably because of the water solubility of the nicotine, making its complete retention in the oil very difficult if not impossible. However, Cressman (1938) reports some success in the use of nicotine with oil against the red scale. One part of nicotine to 1800 parts of total spray was used with 1 per cent heavy petroleum oil in the spray.

The successful use of nicotine sulfate with oil in the control of the greenhouse thrips, *Heliothrips haemorrhoidalis*, is probably an example of an additive effect of the independent action of two insecticides, each of which has considerable in-

[1] Fifty-six per cent distilled at 636° F., viscosity 70 seconds Saybolt at 100° F., unsulfonatable residue 90 per cent.

secticidal value, but not sufficient to be independently successful as a control measure. The two insecticides must also exert their toxicity in different phases of the emulsion, the nicotine sulfate being practically insoluble in oil.

In the control of greenhouse thrips on citrus, 1 pint of nicotine sulfate is added to the regular dosage of oil used in the control of scale insects or citrus red mite.[1]

Oil and Pyrethrum.—The first indication of the merits of oil-pyrethrum spray in the control of greenhouse thrips resulted from the investigations of A. M. Boyce (Boyce & Mabry, 1937), who found that the spray showed considerable promise, although at that time an oil-nicotine sulfate combination was considered to be more effective. At present, however, pyrethrum has supplanted nicotine sulfate as the main greenhouse thrips control measure. One fourth pint of pyrethrum extract per 100 gallons is added to the regular oil spray (1.67 per cent light-medium oil) at the time, that the oil spray is used to control scale insects or other pests. Three weeks later 0.75 pint of pyrethrum extract is added to 0.5 gallon of oil per 100 gallons of spray to complete the thrips control program.[1]

Pyrethrum extract has been found to have little or no toxicity to citrus scale insects when used with oil. This is an unfortunate circumstance in view of the ease with which oil-pyrethrum sprays can be prepared.

Oil and Dinitro-o-cyclohexylphenol.—Since the earliest investigations with dinitro-o-cyclohexylphenol in the control of citrus pests in 1935 (Boyce *et al.* 1939), numerous tests have demonstrated the high degree of toxicity of an oil solution of this compound to many citrus pests, including even the red scale.[2] Unfortunately the injury caused by this compound to foliage makes its use with oil impossible under present conditions. Further investigation may lead to a means of using dinitro-o-cyclohexylphenol with oil, without the risk of tree or fruit injury.

Oil and Lethane 410.—*Lethane 410*, a proprietary aliphatic thiocyanate compound, has been extensively investigated as to its possible merits as a toxicant which might be used with spray oil on citrus trees. Excellent results were obtained from *Lethane 410* at 0.0625 per cent combined with light-medium oil at 0.5 per cent in extensive tests made on black scale.[3] No deleterious tree reaction was observed. The material was found to be too expensive, however, to compete with existing methods for the control of the black scale. Also, the material was ineffective against the red scale.

Oil and Rotenone-bearing Powders.—The ground roots of rotenone-bearing plants have been added to low dosages of oil (usually 0.75 or 1 per cent) to form a spray which has had an important place in the black scale pest control program. The advantage in the use of this material lies in the fact that reduction in dosage of oil is desirable from the standpoint of tree reaction and fruit quality. Likewise black scale can be satisfactorily controlled by oil-rotenone powder sprays later in the pest control season than had formerly been possible. The disadvantage in the use of the material lies in its inability to effect even the moderate degree of control of red scale which results from the larger dosages of oils used for black scale, and in its inability to control the citrus red mite.

The ability of rotenone-bearing powders to increase the effectiveness of an oil spray without the rotenone being dissolved in the oil to any appreciable extent has led to much speculation as to how the increased effectiveness of the oil is brought about. The ground roots and various powders which are combined with them to make up the proprietary rotenone-bearing powders are preferentially wetted by oil and are consequently deposited on the scale body with the oil film. A possibility of a suspension of the ground root particles in the water phase, however, must not be discounted, and possibly some of the toxic material is deposited by the water. Apparently either a sufficient amount of toxic principle is dissolved in the oil to result in an appreciable toxicity to the scales or the derris or cube is able to enter the insects' bodies in some other way, possibly in some such manner as suggested by Tisch-

[1] Bartlett, Blair R., 1941. Notes on the control of greenhouse thrips, on file at the Citrus Experiment Station, University of California.

[2] Ebeling, Walter, 1937. Laboratory experiments on the red scale. Unpublished data on file at the Citrus Experiment Station, University of California.

[3] La Due, J. P., 1936. Laboratory notes on the use of *Lethane* with oil. On file at the Citrus Experiment Station, University of California.

ler (1935), who believes that an extract of the ground root may enter the bodies of insects by means of their body exudates, whose osmotic pressure is increased by an increase in the concentration of the fluid. Osmotic flow from the underlying hypodermal glands is then induced until equilibrium is restored, according to Tischler's theory.

It has been shown by Boyce *et al.* (1940) that a true solution of extractives in oil is far more effective than the ground root suspension. Thus, while the addition of the ground root makes possible a reduction of oil dosage from 1.5 or 1.67 per cent to 0.67 or 1 per cent, the toxic solutions made possible a reduction of oil dosage to as low as 0.25 per cent. Suitable solubilizers (Boyce *et al.* 1940) were used to incorporate the extracts of rotenone-bearing plants into the oil.

Oil and Rotenone or Total Extractives of Rotenone-bearing Plants.—Since extractives of rotenone-bearing plants are not sufficiently soluble in oil to make possible any appreciable increase in the insecticidal effectiveness of the oil against citrus pests, solubilizers (mutual solvents) must be used to bring about a stable suspension or solution of the extracts in the oil. Experiments at the Citrus Experiment Station of the University of California extending as far back as 1926 (Smith, 1929) with many alcohols, aldehydes, ketones (LaDue, 1938), esters, resins and a variety of natural products, has revealed only three which were considered suitable as solubilizers for derris extract and spray oil used in black scale control (Boyce *et al.* 1940). These were dibutylphthalate, 2(4-tertiary butylphenoxy) ethanol and an oil-soluble phenolic resin known as *Cardolite 627*.[1] Cressman (1938) used a solution of 30 per cent trichloroethylene and 70 per cent dibutylphthalate successfully as a solubilizer for timbo extract. English (1939) found that a pine oil extract of derris containing 5 per cent rotenone increased the effectiveness of oil sprays to a greater extent if diglycol laurate, diglycol oleate and sodium oleyl sulfate were either dissolved or suspended in the oil in the proportion of 1 part to 9 parts of oil than when dissolved in straight oil.

In red scale control, which requires a high dosage of oil, regardless of the toxicity of the oil, and consequently demands a greater dilution of the toxicant (Ebeling 1940), only 2(4-tertiary butylphenoxy) ethanol and *Cardolite* were found to be capable of maintaining an apparently complete and relatively stable solution of derris extract in oil. However, the former had such great emulsifying and wetting properties that too little oil was deposited by the spray when the oil was used at the usual percentage of 1.67 to 2 per cent. Also occasionally necrotic areas in the foliage were caused by this solubilizer at the concentrations used. The *Cardolite* remained as the only practicable solubilizer to which access was had for experimental work on the use of extracts of rotenone-bearing plants with oil spray for use against the red scale.

A consideration of the properties a suitable solubilizer must possess for the incorporation of rotenone or extractives of rotenone-bearing plants into oil which is to be used with water may be of interest at this point. The solubilizer must fulfill the following requirements: (1) dissolve the extractives, (2) produce a stable suspension, or, preferably, a solution of the extractives in oil, (3) be insoluble in water, or sufficiently insoluble so that it will remain practically entirely in the oil phase, (4) have no adverse effect on the emulsibility of the oil or the oil-depositing properties of the spray, (5) have no adverse effect on the toxicity of extractives, and (6) be harmless to trees and fruit. Experience has shown that a solubilizer which will meet all of these requirements is rare indeed.

Preliminary tests with *Cardolite* have already been reported by the writer (Ebeling 1940). The material was selected as the only one of a series of oil-soluble resins which had all the necessary characteristics for use as a solubilizer for derris extractives and spray oil. Some resins failed only as regards their undesirable effect on the finished toxic oil emulsion. *Cardolite* exhibited a similar tendency at the higher concentrations at which it was first thought necessary to use the material. Further research, however, brought to light means of solving this difficulty by the use of emulsive oils.

The research of Boyce *et al.* (1940) showed that it was possible to obtain as good results against the black scale with

[1] A formaldehyde reaction product of cashew nut liquid. The writer is indebted to the Irvington Varnish and Insulator Company, Irvington, New Jersey, for a generous supply of *Cardolite 627* for experimental purposes.

0.25 per cent light-medium oil with a suitable solubilizer with 11.75 per cent derris extractives (34 per cent rotenone) used at 0.0625 per cent as was obtained with 1.67 per cent of the oil alone. A slurry of oil, 2(4-tertiary butylphenoxy) ethanol and ground derris root was also used with success. Apparently the solubilizer extracted the extractives from the ground root and brought it into solution with the oil.

In red scale experiments, 0.5 pint of a toxic stock solution[1] to 1.9375 gallons of light-medium oil added to 98 gallons of water with 4 ounces calcium caseinate spreader has measurably increased the effectiveness of the oil spray over that which would be expected from a 2 per cent concentration of light-medium oil spray without the addition of the toxicant.

The effectiveness of derris and cube extract is best demonstrated by the great increase in the toxicity of a kerosene spray made possible by the dilution of the above stock solution with 39 parts of kerosene (resulting in 0.031 per cent rotenone in the kerosene). Used at a 10 per cent dosage with 4 ounces calcium caseinate spreader per 100 gallons, the toxic kerosene often kills practically all red scale hit by the spray on any part of the tree. Kerosene by itself at a 10 per cent dosage is too ineffective to be of value as a commercial control measure for the red scale.

There is greater room for improvement of the relatively ineffective light oil sprays than of the heavy oil sprays. This is a fortunate circumstance in view of the fact that the lighter oils are desirable because their relatively greater rate of evaporation makes them less detrimental to citrus trees and fruit. The inability to use the lighter oils in the past has been due to their relative ineffectiveness, especially as against the red scale. If the light petroleum fractions can be made effective by the addition of toxicants, an improvement may be effected not only with regard to pest control but also with regard to the problems relating to tree reaction and fruit quality which have in the past been related to oil spray.

[1] The stock solution consists of 4.16 per cent derris extract (30 per cent rotenone), 20.84 per cent Cardolite 627, and 75 per cent light-medium oil; all percentages by weight. The solution contains 1.25 per cent, by weight, of rotenone. The derris extract is added to the Cardolite at a temperature of 125° C. and is dissolved in 1 or 2 minutes, then immediately further diluted with oil to reduce the temperature of the solution below that which is considered detrimental to rotenone.

SUMMARY.—Oil sprays, though increasingly important in the general pest control program, have been nevertheless somewhat limited in insecticidal effectiveness, especially against certain pests. Increase in insecticidal effectiveness of an oil spray may be effected by the addition of materials which can improve the spray by physical or by chemical means.

Among the physical means of improving oil sprays may be mentioned improvement in emulsibility, spreading, and oil-deposition on the tree and insect surfaces by means of improved emulsifiers and spreaders. Walnut-shell flour and other finely-divided solids have been found to increase surface capillarity, making it possible for sessile insects to draw oil off the tree surface to their bodies to an extent not previously possible. The changes in the physical properties of oils by the addition of certain solutes has led to improvements by making possible preferential wetting, penetration control, and other phenomena which make for a more efficient and extensive use of oil sprays.

Materials added to oils may result in improvement of the resulting sprays by (1) making possible the treatment of two pests, requiring different insecticides, with one spray treatment, (2) increasing the effectiveness of the spray because of the additive effect of the independent actions of two or more insecticides, (3) increasing the effectiveness of the spray because of the apparent synergistic action often resulting from combinations of certain compounds with oil even though these compounds may by themselves have little or no insecticidal value against the pest in question, and (4) by making possible the penetration of compounds which have a high independent toxicity but are not able to penetrate to the insect or into its body.

Examples of materials added to petroleum oil spray which have been used either experimentally or in actual citrus pest control practice are (1) cryolite in orange worm control, (2) *Selocide* and wettable sulfur in citrus red mite control, (3) various sulfur compounds in citrus red mite and citrus bud mite control, (4) lime-sulfur used with miscible oil in control of unarmored scale insects and citrus red mite, (5) nicotine sulfate in greenhouse thrips control and nicotine in red scale control experiments, (6) pyrethrum in

greenhouse thrips control, (7) dinitro-o-cyclohexylphenol in scale control experiments, (8) *Lethane* in black and red scale control experiments, (9) preparations including ground rotenone-bearing roots in black scale control, and (10) the extractives of rotenone-bearing plants incorporated into oil by means of solubilizers and used in the control of scale insects.—9-2-41.

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RESISTANCE OF PLANTS TO INSECT ATTACK

This note may call attention of entomologists who are interested in insect resistance to the recent publication of a paper with the same title as that listed above, by R. O. Snelling. This article gives a short dissertation regarding insect resistance, and a bibliography of the papers which have been published up to date, including 567 titles. This is the most nearly complete bibliography on insect resistance which has yet been published. The paper appeared in *Botanical Review*, Vol. 7, No. 10, pages 543–586, Oct., 1941.—11-23-41.

J. H. BIGGER

Physiological and Physical Effects of Spray Oils on Deciduous Trees

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This is a brief review of available parts of the extensive recent literature on the effects of petroleum and tar oils on sprayed plants, especially deciduous fruit trees. Herbaceous plants are necessarily mentioned for comparison and accessory information.

Spray oils should be regarded as medicines to be used only when they are reasonably expected to do more good than harm, for oils have some injurious effects on plants. Thus, there is a narrow margin of safety for predominantly beneficial use of oil sprays. As oils are used extensively on leaves and stems of plants, it is important to summarize information on symptoms of oil injury and conditions affecting oil injuries. These are combined with reports of insect control without serious injury to plants.

Phytotoxic and Innocuous Oil Sprays.—Overley & Spuler (1928) concluded that sprays of 4 per cent oil did not injure dormant trees. Farrar & Kelley (1935) and Young & Morris (1933) found that 2 to 8 per cent oil emulsions as dormant sprays applied annually for 5 to 10 years did not measurably retard growth of trees. Some oils disturbed fruit color development. Oil injury to buds resulted in flowers opening without many leaves (Spuler *et al.* 1931a). Of the varieties of apples tested, Stayman and Winesap were the most susceptible to oil injury. Increased starch probably was due to faulty conduction in leaves sprayed with oil (Spuler *et al.* 1931b). More than 3 summer oil sprays decreased the size of fruit and the set of buds for the following crop (Overholser & Overley, 1930). Headlee *et al.* (1930) reported that the oil-pyrethrum spray decreased the size of the fruit buds for the following year, and that white oils are liable to cause chlorosis and fruit drop. Ginsburg (1929) gave evidence that oil sprayed leaves contained more chlorophyll than unsprayed leaves. Ackerman (1923) said that 3 per cent oil sprays in hot weather caused small, dark, slightly sunken fruit spots. Oil sprayed fruit was delayed in coloring and oily fruit held too much dust (Davis *et al.* 1927). Marshall & Groves (1936) found that oils tended to decrease arsenical injury. Burroughs (1923) mentioned that oil sprayed leaves may contain no starch.

Young & Morris (1933) and Young (1934b) reviewed literature on oil sprays of apples, and reported the following main symptoms of oil injury: premature defoliation; large brown spots; purple spots; dry-green spots; hypophyllous brown, purple, and silvery spots; and chlorotic translucent spots in the leaves. Emulsions containing 4 to 16 per cent oil usually killed flowers. Abnormal fruit color, russeting, cracking, and large red-bordered black spots were symptoms of injury caused by 4 to 8 per cent oil emulsions sprayed on fruit. Buds usually were not injured by 4 per cent oil emulsions even when applied as delayed dormant sprays. Emulsions of 6 or 8 per cent oil sometimes killed buds, especially when applied as delayed dormant sprays. Ginsburg (1940a) commercially tested semi-refined spindle oils on apple leaves and found no serious injury from 6 sprays of 0.7 per cent oil emulsion made from oil that was 83 per cent unsulphonatable, with a viscosity of 70 sec. The cost of this oil was less than half the cost of the highly refined oils generally used on leaves. The oil and arsenic sprays caused only tolerable amounts of plant injury.

Oils passing from leaves into twigs often killed the twigs, and prominent canker lines later developed, separating the living and dead bark. Abundant oils sometimes caused yellow and gray blisters in the bark. Many of the symptoms of oil injury were illustrated (Young & Morris 1933: Young, 1934b). In unpublished research, it was found that poplar leaves showed typical translucent angular mottling from oil.

Sulphonatable Residues.—Toxicity is essentially a chemical property of an oil, depending mainly on the percentages and qualities of the unsaturated hydrocarbons. White spots and epiphyllous purple spots in apple leaves were caused

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only by certain oils which showed that the nature as well as the concentration of sulphonatable chemicals influences the symptoms of injury caused by oils (Young 1934b). Oils for 2 per cent oil sprays on apple leaves should not be more than 17 per cent sulphonatable, whereas oils for 4 per cent oil sprays on dormant twigs should be only 30 to 40 per cent sulphonatable. Close attention should be given to the sulphonatable residues in spray oils (Young & Morris 1933).

TESTING TOXICITIES OF PETROLEUM OILS.—Two methods were used to determine whether apple leaves could tolerate questionable petroleum oils. The undiluted oils were tested quickly and easily by placing drops of them on apple leaves, using unsulphonatable white oils for comparison. The rapidity, severity, and abundance with which the symptoms of oil injury appeared showed the toxicity of each oil to apple leaves. Oils that killed large areas of leaves within a week were too toxic for use in sprays on leaves (Young 1934b). The other method was to inoculate agar slants with bread mold and cover the slant with the oil to be tested. Only oils permitting luxuriant growth of the mold were sufficiently purified to use safely on apple leaves (Young, 1934a). Thus, the probable toxicity of a petroleum oil to apple leaves could be tested easily and quickly before the oils were used as sprays.

VISCOSITY.—Oil of 70 sec. viscosity generally is properly viscous for summer sprays (Ginsburg, 1940a). Spuler *et al.* (1931b) found evidence that oil of 70 sec. viscosity discolored the calyx end of Yellow Newtown apple fruits, indicating unusual susceptibility to oil injury. Oils with viscosities of 100 to 220 sec. Saybolt were satisfactory in dormant sprays (Spuler, *et al.* 1931a). Using the Hibernal variety of apple, Young (1934b) found no correlation between amounts of oil injury and oil viscosities ranging from 38 to 410 sec.

EFFECT OF SPRAY OIL ON TRANSPIRATION AND RESPIRATION OF LEAVES.—Burroughs (1923) and Kelley (1930b) showed that spray oils decreased transpiration. Lime in sprays tends to increase transpiration from certain species of leaves, and 0.5 per cent oil added to a spray tends to overcome this tendency of lime. Dormant oil sprays applied by Kelley (1930a) resulted in accelerated respiration rate, whereas the oils applied in delayed dormant sprays retarded the respiration rate. Oils increased the respiration of leaves. Green & Johnson (1931) concluded that oils with 16 per cent or more sulphonatable residues increased the respiration rate of leaves, whereas the oils less than 16 per cent sulphonatable decreased respiration. Oils have 2 main effects on leaves: (a) a physical effect tending to decrease respiration by plugging the stomata, intercellular spaces, and tracheae, and (b) a chemical effect in which nonlethal toxic chemicals increase respiration. Accordingly, the effect of the oil on respiration depends on the predominance of the physical or the chemical effect (Young & Morris, 1933). Several unsaturated hydrocarbons are unsulphonatable, which may explain an increased respiration resulting from an unsulphonatable oil. Burroughs (1923) stated that oil on fruit may cause partly anaerobic conditions in it. Hoffman (1934), Schroeder (1935), and G. W. Young (1934) all reported that oil sprays resulted in decreased absorption of carbon dioxide by leaves.

PENETRATION AND DISTRIBUTION OF PETROLEUM OILS IN PLANTS.—Following the work by Knight *et al.* (1929) on oil penetration in citrus, Young & Morris (1933) and Young (1934b, 1935a) described and illustrated the penetration and distribution of petroleum oils in apple and other plants. Large amounts of oil penetrated leaves from oil sprays. Undiluted oils with viscosities of 50 to 108 sec. penetrated the lower sides of apple leaves and caused translucent spots within 2 to 60 sec. The oily spots were yellowish green by transmitted light and blackish by reflected light. Such oily translucent spots enlarged quickly and thereafter changed very little in appearance, even in the leaves that were dried and kept in the herbarium during 2 to 5 years. Large amounts of oil passed from oiled apple leaves into their twigs. The oils became distributed widely between the parenchyma cells and in the tracheae. Oil was found in an apple stem 488 days after oil had been sprayed on leaves then attached to this stem. In fruits, oil entered through the lenticels and passed between the parenchyma cells and into the tracheae. Oil injected into apple limbs was found 4 to 12 months later, 5 to 88 cm. from the

injection points. The oil in these limbs was mainly in the tracheae and between the parenchyma cells. In onions, oils were soon conducted from the leaves into the roots or from the roots to the leaves, much of the conduction of oil apparently being between the parenchyma cells. Decane likewise was conducted from onion leaves to the roots (Young 1935c). Tomatoes absorbed oil from the soil (Fuller & Leadbeater, 1935). Kendall (1932) tested oil penetration into leaves and concluded that oil soon reaches a state of equilibrium and remains indefinitely in the position first occupied. Oils evaporate slowly from leaves, but most of the oil is removed from trees by defoliation.

The kind of emulsion affects the method of oil penetration and the resulting symptoms (Young & Morris, 1933). Calcium caseinate emulsions broke quickly and apparently penetrated as free oil into apple leaves, commonly causing translucent angular leaf spots. In contrast, *Cresoap* emulsions of oils were stable and apparently penetrated as emulsions into leaves, usually without making translucent angular spots. Ammonia-casein oil emulsions were intermediate in stability and occasionally made translucent angular leaf spots, which is evidence of penetration by free oil. The excellent quality of *Cresoap* used in making miscible oil was an automatic emulsifier (Young 1936). The miscible oils emulsified instantly on contact with water, without the usual external agitation. Thus, it is probable that solutions in leaves may be included in *Cresoap* emulsions of 8 or 16 per cent oil that penetrates into leaves. Petroleum oil often was found inside living cells of plants. Passage of petroleum oil through protoplasm was explained by the oil-mass theory (Young 1935b; Clayton 1935). These phenomena of oil penetration and distribution between and into plant cells may also be involved in the slow killing of insects by slightly toxic oils.

FREEZING EMULSIONS.—In the early days of oil spraying, there was worry that freezing of dormant oil sprays on trees would probably increase their injuriousness by breaking the emulsions, so this phase of the problem was investigated by Young & Morris (1933). Oil sprays froze on apple trees on 3 dates but the freezing made no apparent difference on the effect of the sprays. *Cresoap* emulsions of 4 per cent oil tended to re-emulsify in melting, and calcium-caseinate-oil emulsions commonly released their oil soon after spraying regardless of freezing, so freezing is not expected to increase the injurious effect of oil emulsions (Young, 1934c and Clayton, 1935). Hoerner (1929) stated that freezing did not damage oil emulsions made with *Penetrol*. Newcomer & Yothers (1931) found that freezing caused no injury to trees sprayed with oil in February. In contrast, very cold weather following oil sprays in the fall resulted in serious injury to the trees. Probably the trees were pre-dormant when sprayed. Felt & Bromley (1932) decided that freezing was definitely harmful to trees sprayed with oil.

OTHER CONDITIONS AFFECT OIL INJURIES TO TREES.—Oil sprays should not be applied at temperatures below 40 F. (Felt and Bromley, 1932). Trees were injured by oil sprays applied at 90 F., so this is the maximum temperature for safe spraying with oil (Davis *et al.* 1923). Drought or fertilizer deficiency increased the susceptibility of apple to oil spray injury (Spuler *et al.* 1931b, Young & Morris 1933, and Davis *et al.* 1927). Hartzell (1936) cautioned that it is dangerous to spray oil on winter injured trees. Oil injury is influenced by the fruit load of the tree, number of sprays, concentration of sprays, amount of water and fertilizer in the soil, temperature and humidity of the air, variety of tree, and health of the tree (Spuler *et al.* 1931b). Buds were susceptible to injury by oil when sprayed in the critical period of bud development in the spring (Spuler *et al.* 1931a). Quick-breaking emulsions, such as those made with calcium caseinate, deposited more oil and caused more plant injury than did stable emulsions. Hence, spraying in windy weather and overspraying should be avoided, as such spraying builds multiple layers of oil. Juvenile leaves apparently were more susceptible to oil injury than were mature leaves. Emulsions of 4 to 16 per cent oil caused serious necrosis and dwarfing of juvenile apple leaves (Young & Morris 1933).

KEROSENES AND DECANE.—Kerosene emulsions were recommended 70 years ago, and there is renewed interest in kerosenes as insecticides. Moore & Graham (1918) concluded from their tests

that pure kerosenes usually injured leaves severely, whereas 3 to 5 per cent kerosene sprays caused little or no injury. Kerosenes penetrate leaves very quickly and evaporate rapidly. The kerosenes with only 1 to 4 per cent of sulphonatable residues caused no injuries or only mild injuries in potato leaves, while kerosenes with 16 to 22 per cent of sulphonatable residues quickly killed potato leaves (Young 1935a). Allen & Carpenter (1940) tabulated the effects of undiluted kerosenes and very light oils on 10 species of vegetables. Oils from Pennsylvania crudes were a little less toxic than those from Midcontinent crudes. Pea, bean, swiss chard, tomato, turnip, potato, and beet were very susceptible to oil injury, while spinach, cucumber, and cabbage were resistant. Small amounts of medium viscosity highly refined kerosenes did not injure the sprayed plants. Toxic kerosenes were used in killing buckthorn (Dietz & Leach 1930).

It was important to test, separately, one of the definitely known hydrocarbons commonly occurring in crude oil. Decane resembling kerosene was selected for this purpose. Decane caused ring spots and white and brown spots in apple leaves. It also killed juvenile apple leaves and caused cankers in their twigs. Decane killed dormant apple buds. Although pure decane was very toxic to apple leaves, 25 and 50 per cent decane mixed with a white, unsulphonatable oil did not make the oil more toxic (Young 1935c).

COAL TAR AND PINE TAR OILS.—Ferguson & DeLong (1940) compared the effects of petroleum and tar oils, and concluded that dormant peach and apple trees were not injured by 2 to 5 per cent tar oil emulsions. Ginsburg (1940b) used 0.66 per cent tar oil with 3 per cent petroleum oil in spraying apples without serious injury. Harley & Moore (1939) used 2 per cent toxic tar oil to kill most of the flowers on apple trees. This tar oil also injured some leaves, buds, and fruits. Spray oils are mainly insecticides, but deOng (1931) dissolved copper resinate in pine tar oil to increase the fungicidal effect of the copper compound.

OIL SPRAYS ON PEACHES.—Swingle & Snapp (1931) gave an extensive bibliography and stated that 3 to 6 per cent oil sprays slightly injured opening peach buds. Red lubricating oils caused severe defoliation and twig injury at a concentration as low as 1.5 per cent oil in summer sprays. Apparently a high unsulphonatable residue indicated a low toxicity to leaves. There was no evidence of cumulative injury from dormant oil sprays one year apart. Fuller & Leadbeater (1935) tested fuel oil on peaches. Frost (1932, 1935, 1936) stated that some 1 and 2 per cent oil emulsions caused little or no injury to peach leaves. He illustrated oil injury resembling symptoms of bacterial shot hole. Sulphur and oil combinations cause slight injury to weakened peach trees (Frost 1937).

Driggers (1928) found that 4 applications of 1 per cent oil spray caused slight chlorosis, defoliation, and fruit drop. Chandler *et al.* (1926) reported that 2 per cent oil emulsion caused serious defoliation while 1 per cent oil emulsion caused only slight injury. Britton (1928) mentioned that peach and plum trees are very susceptible to oil injury, and that weak trees are especially susceptible. Tank-mix emulsions saved half of the cost of material and did not injure dormant trees (Borden 1934, 1936).

Tank-mix oil emulsions were used on a dormant peach orchard near Jacksonville, Texas in January 1939. A lubricating oil of low refinement was mixed with blood albumen and water in a large power sprayer at the rate of 4 per cent oil and sprayed on thousands of trees. The sprayer had an ordinary agitator revolving about 100 times per minute, and one of the agitator blades worked only a part of the time, so apparently the agitation was very inadequate. During the following spring, many of the peach limbs and whole trees died with symptoms closely resembling symptoms of oil injury in apple trees. Probably the power sprayer applied nearly pure oil to many of the peach limbs. In contrast, other dormant peach orchards were properly sprayed here with 3 per cent stable oil emulsions for the last few years, without evidence of oil injury to the trees. No spray machinery with agitation adequate for applying tank-mix emulsion is locally available, so peach growers here are advised to use only the best grades of stable commercial emulsions and miscible oils.

OIL SPRAYS ON OTHER PLANTS.—Oil sprays have been tested on many species of plants to determine possible commer-

cial value. Chandler *et al.* (1926) concluded from their tests that 1 and 2 per cent oil emulsions did not injure plum, cherry, and grape, but that 2 per cent emulsions killed spots in leaves of pear, walnut, rose, and tomato. Thus, plants differ in their susceptibility to injury by oil. Felt and Bromley (1932) said that sugar maple, black walnut, butternut, beech, and spruce were very susceptible to oil injury. They listed tests on many species of plants. Beech trees were badly injured by fall sprays but were only slightly injured by spring sprays, but all tested trees showed enlarged lenticels in the bark. Petit (1928) reported that *Volck* oil spray did not injure pear trees, and that oil sprays caused little or no injury to spruce trees. Cleveland (1931) found that elm trees were not injured by oil spray. Davis *et al.* (1925) said that cherry, pear, plum, gooseberry, grape, blackberry, peony, lilac, dogwood, rose, walnut, maple, and onion leaves were not injured by 2 per cent oil sprays. DeOng (1926) tabulated the results of oil sprays on prune trees. Low refined oils caused mottling, yellowing, and killing of leaves. Trees suffering from drought were especially injured by oil. Crowley (1930) said that 2 sprays of summer oil were safe on cranberry, but some concentrated oil sprays injured the plants. Mahoney (1930) mentioned that oil sprays removed the waxy bloom from grape fruits. It is dangerous to use oil sprays on weak pear trees according to Hartzell (1931, 1936).

SUMMARY.—Petroleum oil sprays injure apple leaves by dwarfing or killing whole leaves, and by causing brown, purple, white, dry-green, and oily translucent spots in the leaves. Oils may kill buds and interfere with proper coloring of fruit. The oils penetrate leaves quickly and pass between the cells and into the tracheae of the leaves and their twigs. Oils for use on apple leaves should be 83 to 90 per cent unsulphonatable with viscosities of 70 and 80 sec. for most varieties of apples. For dormant sprays on apple, oils should be 60 to 70 per cent unsulphonatable with viscosities of 120 to 220 sec. Proper temperatures for application of oil sprays are 40 to 90°F. Oil emulsions may be applied at concentrations of 0.5 to 2 per cent oil on leaves and 4 to 8 per cent oil on dormant buds. Oils decrease transpiration of leaves. Respiration of leaves is increased or decreased by oils depending on the predominance of the chemical or the physical effect. Freezing of oil sprays on trees probably does not seriously change the effect of the emulsions. Effects of oil sprays are variable depending on the species or varieties of plants, suffering of the plants from drought or fertilizer deficiency, load of fruit on the trees, number and concentration of sprays, sulphonatable residues and viscosities of the oils, type of emulsion, condition of leaves or buds, and temperature of the air. Improper oil sprays may kill peach leaves, twigs, and whole trees. Tank-mix emulsions must be extremely well agitated to be safe on trees.—9-2-41.

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Toxicants Used with Petroleum Oil Sprays for Deciduous Fruits

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A consideration of the toxicants used with petroleum oil sprays may well follow the organization of Roark (Anon. 1940) wherein the materials are grouped into (1) insecticides of plant origin, (2) synthetic organic insecticides, and (3) inorganic insecticides.

The toxicants used with oil might be classified into three groups depending upon the efficiency of their action. These groups might be called: (1) "Inhibitory," wherein the efficiency of the mixture is definitely less than the sum of the efficiencies of each of the components; (2) "Additive," wherein the efficiency of the mixture is approximately equal to the sum of the efficiencies of each of the components; and (3) "Multifold" wherein the efficiency of the mixture is considerably greater than the sum of the efficiencies of the components. This latter type of action should not be confused with synergistic action, since by definition (Macht 1929) synergism includes both inhibitory and multifold mixtures.

In this paper some of the more common toxicants will be reviewed in the arrangement suggested by Roark, and some of the most recent experimental work will be studied with particular reference to the classification of their mode of action.

Before proceeding to examine these toxicants two types of substances, which may or may not be regarded as *added* toxicants must be considered. These are emulsifying agents, and unsaturated hydrocarbons. The common emulsifying agents (Shepard 1941) include soaps such as potassium fish-oil soap, sodium oleate, and triethanolamine oleate; sulfated and sulfonated preparations such as sodium lauryl sulfate, sodium stearyl sulfate and sodium oleyl sulfate; proteins such as milk, eggs, and glue; resin soap or "sodium resinate"; casein-lime and casein-ammonia; blood albumin; saponin; phenol and cresol (in conjunction with soap); bentonite clay and bordeaux mixture.

While some of these emulsifying agents such as blood albumin and bentonite clay, are known to be relatively non-toxic, others have been shown to possess marked toxicity to certain insects. Yothers & Griffin (1940) found that an alkylated naphthalene sulfonate at 4 pounds per 100 gallons produced a 58 per cent kill on the woolly apple aphid; a sulfonated petroleum oil at one half gallon per hundred killed about 13 per cent. Sodium oleate at one half pound per 100 gallons killed 11 per cent of the apple aphid. Hansberry & Norton (1941) tested saponin and sodium oleate on *Aphis rumicis*. One per cent saponin gave a 1.7 per cent mortality; and 0.25 per cent sodium oleate gave 22 per cent mortality. Fulton & Howard (1938) found that sodium lauryl sulfate at 0.3 gram per liter killed 58 per cent of the milkweed bug, *Oncopeltus fasciatus* (Dall).

Peterson (1918) found that phenols and cresols were highly toxic to aphid eggs. Headlee & Ginsburg (1929), and Ginsburg (1940), recommended the use of 0.5 per cent crude cresylic acid in a 3 per cent petroleum oil emulsion, applied in the delayed dormant period for the control of apple aphids. Hough (1939a) found that the range in control on rosy apple aphid resulting from cresylic acid at 2 quarts per 100 gallons and 3 per cent oil is the same as for 3 per cent oil alone. However, over a three-year period the average con-

trol where cresylic acid was used was slightly higher.

Porter & Sazama (1930) tested a series of summer and dormant sprays on San Jose scale on peach and apple, using oil alone and combined with bordeaux mixture. In summer applications on apple the oil emulsion at 2 per cent alone gave a 91 per cent control. When 3-5-50 bordeaux was added to this emulsion the control was reduced to 63 per cent. When bordeaux was used as the emulsifying agent the control was inferior to that obtained with oil-emulsion and bordeaux. In dormant sprays on peach, 1 per cent oil emulsion alone controlled 99.5 per cent whereas 1 per cent oil emulsion with 4-6-50 bordeaux controlled only 69 per cent. Higher concentrations of oil, (1.5 per cent or higher) were not reduced in efficiency by bordeaux. The explanation was advanced that the bordeaux absorbs an appreciable amount of the oil in the lower oil concentrations, thereby reducing their efficiency. Worthley & Steiner (1939) found that oil emulsified with 2-6-100 bordeaux gave a good kill of red mite eggs.

Whether or not the unsaturated hydrocarbons can be considered as toxic materials seems to be a moot question. De Ong (1926) found the unsaturated hydrocarbons to be more toxic than the saturated hydrocarbons. English (1928) concluded that a saturated oil, because of its influence in some cases on the stability of the emulsion, may be more effective than an unsaturated oil. Swingle & Snapp (1931) tested various oils against the San Jose scale and concluded that the unsulfonated residue was apparently without effect upon toxicity. Cressman & Dawsey (1936) tested oils of widely varying sulfonatable content against the camphor scale, *Pseudaonidia duplex* (Ckll.), and concluded that there was no relation between the sulfonatable content and the toxicity of the oil.

INSECTICIDES OF PLANT ORIGIN.—The more common insecticides of plant origin include nicotine, anabasine, pyrethrins I and II, rotenone, rotenoids, quassin, and veratrin alkaloids.

The relative newness of the idea of combining an oil emulsion with a toxicant is best illustrated by the oil and nicotine combination, since this is one of the oldest and best known combinations. Herbert (1931) has traced the first use of oil and nicotine to 1915 (Foster & Jones, 1915). Very little was done with this combination during the next twelve years, until de Ong (1928) reported that free nicotine improved the efficiency of oils as scalicides. Following this, and up to the present, this combination has been widely studied.

Many papers appeared during the next few years which compared the action of oil, alone and combined with nicotine sulfate, for the control of various sucking insects such as aphids, scale, and thrips. Yothers & Griffin (1940) found that nicotine sulfate at 1 to 1,600 increased the kill of apple aphid obtained with oil at 1 gallon per 100 from 78 to 98 per cent, a gain of 20 per cent due to the addition of the nicotine. Hough (1939b) combined nicotine sulphate, 1 pint per 100 gallons, with 3 per cent petroleum oil and obtained an average control of 91 per cent on rosy apple aphid as compared with an 86 per cent control when 3 per cent oil alone was used. Webster *et al.* (1940) tested nicotine sulfate at two thirds pint with one half gallon of oil emulsion per 100 gallons as a cover spray for codling moth control. At harvest the fruit was 63 per cent wormy and the oil-nicotine combination was regarded as of little value against severe infestations. Hartzell & Chapman (1940) held nicotine sulfate concentration constant at 16 ounces and used the oil emulsion at 4, 5, and 6 gallons. The control of rosy aphid was 0, 28, and 64 per cent respectively. The control of aphids using oil emulsion alone at 4, 5 and 6 gallons was 15, 33, and 35 per cent respectively.

The problem created by arsenical residue on apples led to a search for "fixed" nicotine compounds. Nicotine tannate, nicotine peat, and nicotine humate were among the first to be prepared. Dawsey *et al.* (1940) stated that at ordinary spray strength about nine-tenths of the nicotine in nicotine-peat is not soluble in the water. From a list of 9 "stickers" for nicotine-peat, bentonite clay was found to be most effective. But at the same time, nicotine sulfate-bentonite was found to be superior in sticking qualities to nicotine-peat. The authors believed the bentonite with nicotine-peat fixed the water-soluble portion of the nicotine-peat.

Hutson *et al.* (1938) found that the control of codling moth obtained by 8 pounds of nicotine-bentonite exceeded that given by 3 pounds of nicotine-ben-

tonite if a half-gallon of oil emulsion was added to the mixture. They state: "The control secured from this combination cannot be explained altogether upon the basis of ovicidal effect from the oil although this must affect the results." Burkholder *et al.* (1940) found that 4 or 5 pounds of commercial nicotine-bentonite with one half gallon summer oil gave good control of codling moth but required more frequent application than lead arsenate-oil sprays. Harman & Moore (1938) secured very effective control of codling moth with a spray composed of *Black Leaf 155* used at 4 pounds, and summer oil 3 quarts, per 100 gallons of water. Later Harman (1940) suggested adding 0.5 or 1 pint of nicotine-sulfate to the above combination. Harman & Greenwood (1941), working on codling moth, found *Black Leaf 155* at 3 pounds per 100 gallons to be decidedly inferior to oil at 4 pints plus nicotine sulfate at 0.5 pints per 100 gallons. When, however, 4 pints of oil were combined with 1.5 pounds of *Black Leaf 155* the control was about equal to that obtained with the oil-nicotine sulfate mixture.

Apparently the discovery of nicotine tannate, nicotine peat, and nicotine humate has touched off an explosion of research on nicotine. This work has followed three general lines: (1) an analysis and synthesis of nicotine, such as the synthesis of neonicotine (beta-pyridyl-alpha-piperidine) from pyridine (Anon. 1940); (2) a study of related compounds such as nornicotine and quinoline; and (3) the preparation of water-insoluble, non-volatile, stable nicotine salts of organic acids of high molecular weights. Hansberry (1940) compared the toxicities of optically active nicotines and nornicotines in tests on *Aphis rumicis* L. The compounds l-nornicotine, dl-nornicotine, and d-nornicotine were more toxic almost to the same degree than l-nicotine. The d-nicotine was substantially less toxic than l-nicotine. Smith (1940) determined the median lethal concentration of nicotine and some other nitrogenous bases for the eggs of *Lygaeus kalmii* to be as follows: nicotine, 0.11 per cent; quinoline, 0.12 per cent; anabasine, 0.18 per cent; piperidine, 0.29 per cent; pyridine, 19.6 per cent; sodium oleate, 2.0 per cent. Each material was used with 0.25 per cent sodium oleate solution in water.

Norton (1940) studied the distribution of nicotine between the oil and water phases of emulsions. The nicotine was found to be at about the same concentration in the oil as in the water. This means that in a 1 per cent oil emulsion only 1 per cent of the total nicotine is in the oil. A large portion of the remaining 99 per cent of the nicotine may therefore run off in the water during spraying. This difficulty is avoided by Ritcher & Calfee (1937a and b) who recommended the use of 1 per cent free nicotine dissolved in a highly refined petroleum distillate and applied without water as a finely atomized oil in an air blast.

Roark states that new nicotine compounds made by the Division of Insecticide Investigations (Anon. 1940) include its salts with alpha-bromo-palmitic and alpha-bromo-stearic acids. These salts are more soluble in oil than in water and hence, when added to an oil-in-water emulsion, tend to remain in the oil phase, whereas nicotine sulfate and other nicotine salts and also free nicotine go largely into the aqueous phase and are lost when the emulsion breaks on contact with foliage and the water part runs off.

Hansberry & Norton (1941) tested 22 nicotine compounds against *Aphis rumicis*. These compounds included nicotine caseinate, laurate, oleate, naphthenate, silicotungstate, cuprocyanide, and others. These were tested as solutions and as suspensions in water. If the relative solubilities of these compounds is greater in oil than in water they may prove to be of value for use with oil emulsions.

However, Norton (1940) sums up the situation as follows: "A number of oil-soluble nicotine compounds have been proposed, particularly salts of nicotine with high-molecular-weight organic acids, in the hope that the nicotine would be kept in the oil layer. Some preliminary experiments have indicated that although most of these acids are insoluble in water, they form salts which are somewhat soluble in water and which, in addition, yield some free nicotine to the water by hydrolysis. They have much less effect than might be expected in keeping the nicotine in the oil, and some of them actually favor the water more than free nicotine. To insure holding the nicotine in the oil, it is not sufficient to find an oil-soluble compound; the compound must

also be insoluble in water and relatively slightly hydrolyzed."

Anabasine, which is extracted from the plant *Anabasis aphylla* L., possesses the same empirical formula as nicotine and is believed to be an isomer of it (Nelson 1934). Anabasine sulfate has been marketed in the United States by the Russian Government, and a considerable literature, chiefly Russian, has accumulated on this subject (Roark 1941). Several workers in this country have studied anabasine sulfate and compared its toxicity to that of nicotine sulfate. In general, the efficiency of these two materials is about the same and their behavior in combination with petroleum oil emulsions seems to be similar. Yothers & Griffin (1940) found that anabasine sulfate at 1 to 1,000 and 1 to 1,600 possessed the same toxicity for the woolly apple aphid as did nicotine sulfate at the same concentrations. One gallon of oil emulsion per hundred gallons yielded a 78 per cent control of apple aphid, and when anabasine sulfate at 1–1,600 was added to this emulsion the control was 100 per cent. Smith (1935) reported the occurrence of anabasine in *Nicotiana glauca*. Roark (Anon. 1940) states "the finding of a domestic source of this valuable insecticide in *Nicotiana glauca* will free the United States from a foreign monopoly."

Pyrethrum extracts combined with oil sprays have not met with such wide use as the oil-nicotine combination. Webster *et al.* (1940) tested various combinations of oil and pyrethrum for codling moth control and reported most unsatisfactory results. Walker (1932) concluded that petroleum oil emulsion combined with an extract of pyrethrum was inferior to soap combined with this extract. Gnadinger *et al.* (1940) found that 3 per cent dormant oil emulsion killed 16 per cent of overwintering larvae of the codling moth. An oil-pyrethrum extract added to this oil, to give 0.2 gram pyrethrins per 100 cc. killed only 44 per cent. Lockwood (1932) and Lamiman (1933) recommended a finely atomized spray of light oil mixture in which was dissolved about 0.055 per cent pyrethrins for the control of the grape leafhopper.

Some advance has been made in the study of the toxic principles in pyrethrum, and some attempts have been made to produce similar substances. Ginsburg (1930) showed that the volatile essential oils of pyrethrum were non-toxic and concluded that the toxicity was a property of the non-volatile esters, pyrethrins I and II. Hartzell & Wilcoxon (1936) reported on the relative toxicities of pyrethrins I and II. When these esters were applied to aphids as a solution in acetone, pyrethrin I was considerably more toxic than II. When a miscible oil was used as a solvent the difference in toxicities tended to disappear. The conclusion was reached that the relative toxicity of pyrethrins I and II depends almost entirely upon the method of application used. Harvill (1939) tested 22 esters of chrysanthemum monocarboxylic acid (the acidic portion of pyrethrin I) and found none of them was as toxic as the pyrethrins.

Rotenone has not been used with oil on deciduous trees to any considerable extent up to the present time. Several lines of research on rotenone, however, are in progress at present and promise to yield some interesting combinations. Inasmuch as rotenone is insoluble in water and in oil, one promising line of investigation is a search for a mutual solvent between rotenone and oil. Another line of investigation consists of a search for antioxidants to stabilize rotenone mixtures and thereby prolong the period of toxic action. A third study attempts to isolate, identify, and classify as to toxicity the various rotenoid materials. Roark (1940) defined a rotenoid as "a substance other than rotenone but structurally related to it, naturally occurring in leguminous fish-poison plants . . .". Examples of rotenoids are: laevodeguelin, laevo-alpha-toxicarol, sumatrol, and elliptone.

New types of rotenone-oil combinations may follow as a result of the work of Goodhue & Haller (1939) who found that as much as 50 per cent of the rotenone present in derris or cube powders could be extracted by water. The extract is a milky colloid, capable of greater concentration by evaporation under reduced pressure than are solutions in organic solvents. Some attempts have been made to "activate" or increase the toxicity action of rotenone. Hartzell & Wilcoxon (1935) compared the toxicity to *Aphis rumicis* of lauryl thiocyanate and rotenone, alone and in combination. Lauryl thiocyanate at 0.0032 per cent gave 37 per cent control, rotenone at the same concentration 82 per

cent, and the two combined in equal concentrations to form a total of 0.0032 per cent gave 83 per cent control. The rotenone was more toxic than the thiocyanate, but the mixture of the two gave the same control as an equal concentration of rotenone alone.

Quassin, extracted from the wood and bark of *Quassia* sp. and others, has rarely been tested in conjunction with oil. It is insoluble in petroleum oil but readily soluble in hot water or cold aqueous alkaline solutions (Parker 1914). This fact has probably led to its extensive use with soap solutions, and the almost complete neglect of its use with oil. Borodin (1916) reported that a good control of the mealy plum aphid was obtained with a mixture of kerosene emulsion and quassia soap. Clark (1937) has separated two substances, called quassin and neoquassin from *Quassia amara* L. If these substances could be used with a mutual solvent in oil, the combination might prove of considerable value as an insecticide.

The veratrin alkaloids are a complex mixture extracted from false hellebore (*Veratrum* sp.). Although powdered hellebore was formerly widely used its use at present is negligible. The alkaloidal residue from the extraction of *Veratrum* is believed to contain five or more alkaloids, some of which are very poisonous while others are relatively innocuous. Fisher (1940) has separated the alkaloidal residue from *Veratrum viride* into ether-soluble alkaloids and ether-insoluble alkaloids. The latter are practically non-toxic. The ether-soluble alkaloids are about 5 times as toxic to the American cockroach as is arsenic trioxide. Thus, the toxic principles in the veratrin alkaloids, possibly combined with a mutual solvent, may present an interesting toxicant for use with petroleum oil.

SYNTHETIC ORGANIC INSECTICIDES.—The number of synthetic organic compounds which have been tested for toxicity to insects probably runs well over a thousand. Of this number, however, only a few have been found to possess outstanding toxic properties. These include neonicotine, thiocyanates, halogenated organic compounds, derivatives of dinitrophenol, and heterocyclic compounds. (Neonicotine has been mentioned earlier in this paper as a nicotine compound.)

The thiocyanates include several proprietary compounds such as lauryl thiocyanate, lauryl rhodanate, (*Loro*) and β butoxy β' thiocyanodiethylether (*Lethane 420*) (Murphy 1936). Of fifteen organic thiocyanogen compounds tested on *Aphis rumicis*, Hartzell & Wilcoxon (1934) found γ-thiocyanopropyl phenyl ether used at 0.1 per cent to be most efficient. This compound plus a spreader gave controls of 98 and 94 per cent. The spreader *Penetrol* used alone gave 29 and 22 per cent control. Creighton *et al.* (1938) tested β butoxy β'-thiocyanodiethylether in combination with petroleum oil and found that about 0.07 per cent of this thiocyanate plus about 0.1 per cent oil gave a 99 per cent kill of aphids on ornamentals. Grayson (1940) obtained a control of 90 per cent on eggs of the European red mite when 0.4 per cent lauryl rhodanate was added to 2 per cent petroleum oil emulsion, whereas the oil alone at 2 per cent controlled 86 per cent of these eggs. Kearns & Martin (1935) found that the addition of petroleum oil to lauryl rhodanate did not decrease the control of *Aphis pomi*. Petroleum oil alone at 5.0 per cent resulted in a 65 per cent kill of eggs. When 0.4 per cent lauryl rhodanate was added the kill of eggs was 100 per cent. The authors found that cetyl rhodanate was less toxic than lauryl rhodanate. Hough (1939b) tested various combinations of oil and lauryl rhodanate against the apple aphid. The 3 per cent oil emulsion alone gave a control of 53 per cent, but when 0.4 per cent lauryl rhodanate was added to this emulsion the control was about 98 per cent. (Lauryl rhodanate at 0.2 per cent, however, produced serious injury to the trees.)

Halogenated organic compounds such as carbon tetrachloride, ethylene dichloride, paradichlorobenzene, and dichloroethyl ether, have for the most part, not been tested as toxicants in petroleum oil sprays. Snapp & Thompson (1931) tested paradichlorobenzene in petroleum oil as a paint for the control of the lesser peach borer and concluded that this oil was not as suitable as cottonseed oil for the purpose. Ginsburg (1941) tested kerosene alone or combined with 1 per cent dichlorethyl ether without water, against codling moth larvae and pupae. The addition of the dichlorethyl ether did not appreciably increase the killing power of the spray. When the kerosene was emulsi-

fied and diluted to 16 per cent the addition of 2.5 per cent dichlorethyl ether materially increased the efficiency of the spray.

Dinitrophenol and several of its derivatives have been used commercially for the past few years. These compounds include 2-4-dinitro-6-cyclohexylphenol, sodium dinitrocresolate, and 2-4-dinitrophenol. The former, usually called dinitro-o-cyclohexylphenol, has been studied extensively and the literature has been reviewed by Kagy & Richardson (1936) and Boyce *et al.* (1939). A few typical recent studies are as follows: Hartzell (1939) tested oil at 3 per cent with and without dinitro-o-cyclohexylphenol, for the control of the eye-spotted budmoth. The oil alone gave a 26 per cent control whereas when 4 per cent dinitro-o-cyclohexylphenol was added the control was 96 per cent. Hammer (1938) tested petroleum oil, alone and combined with dinitro-o-cyclohexylphenol as an ovicide for the control of scurfy scale on apple. Whereas a 6 per cent petroleum oil alone controlled 91 per cent, a 1 per cent petroleum oil containing 4 per cent of dinitro-o-cyclohexylphenol in the oil controlled 99 per cent.

Boyce *et al.* (1939) used 1.5 per cent petroleum oil alone and with 2.0 per cent dinitro-o-cyclohexylphenol for the control of the walnut scale, *Aspidiotus juglans-regiae* Comst. The oil alone killed 66 per cent and with the dinitro compound killed 74 per cent. Grayson (1940) using dinitro-o-cyclohexylphenol alone at 8 to 14 ounces per hundred gallons obtained kills of red mite eggs ranging from 10 to 56 per cent. When the dinitro compound in this range of concentrations was tested with 2 per cent petroleum oil emulsion the kills ranged from 90 to 95 per cent. The oil alone at 2 per cent killed 86 per cent of the eggs. Hough (1939b) tested wettable dinitro-o-cyclohexylphenol alone, oil alone, and the two combined on the rosy apple aphid. The control was as follows: oil alone 76 per cent, dinitro alone 85 per cent, and the combination 98 per cent. When 9.5 ounces per hundred gallons were tested without oil against the apple aphid, the control approximated 100 per cent.

Hartzell & Chapman (1940) tested a proprietary sodium dinitrocresolate for the control of rosy apple aphid and budmoth. A satisfactory control was obtained with this material alone and the addition of 3 per cent petroleum oil caused a slight decrease in efficiency. Hough (1939a) tested a series of concentrations of dinitro-o-cresol, with and without oil, for the control of the apple aphid. In every case the control obtained with the oil-dinitro mixture was greater than that of the dinitro alone. When the dinitro was used at 0.83 pound per 100 gallons the control of aphids was 64 per cent. When the oil was used alone at 3 per cent, the control was 53 per cent. When the dinitro and oil were combined at these concentrations, the control was 95 per cent.

A few heterocyclic compounds such as phenothiazine and diphenylene ketone oxide or xanthone have been tested with oil. Webster *et al.* (1940) tested phenothiazine and stove oil against the codling moth and found as high as 54 per cent wormy fruit in the sprayed plots. A proprietary xanthone was also tested at 2 pounds per 100 gallons with stove oil. This mixture reduced the wormy fruit to about 9 per cent which compared favorably with standard treatments.

Coal tar distillate is added to petroleum oil sprays as a toxicant in certain cases. Hough (1939a) reported a 53 per cent control of apple aphid when a 3 per cent oil emulsion was used. When 2.5 per cent coal tar distillate was added to this oil emulsion the control was 99 per cent. Ginsburg & Driggers (1938) compared tar oil-petroleum oil emulsion in the dormant season with the standard cresylic acid-petroleum oil spray in the delayed dormant period and concluded that the tar oil mixture was as effective as the cresylic acid mixture. Hammer (1938) tested petroleum oil alone and combined with coal tar distillate as an ovicide for the control of scurfy scale, *Chionaspis furfura* (Fitch), on apple. Whereas 6 per cent of petroleum oil was required to kill 91 per cent of the egg masses, the same efficiency was shown by a 3 per cent mixture of tar oil-petroleum oil containing 37 per cent tar oil.

INORGANIC INSECTICIDES.—The use of inorganic insecticides with petroleum oil is usually done with some objective other than increasing the toxicity of the oil. Thus, oil may be used with lead arsenate to increase the deposit of the latter; or oil may be used with a fungicide to control an insect while the latter controls a dis ease. Many papers have been published on the combination of oil and lead arse-

nate. Only a few of the recent contributions can be discussed here. Sherman (1936) tested lead arsenate with and without oil on codling moth. Lead arsenate, 3 pounds, with summer oil, 1 quart, gave 97 per cent sound fruit, while lead arsenate alone gave 92 per cent. Driggers (1937) compared lead arsenate combined with oil and combined with lime plus milk for the control of the codling moth. The oil-lead arsenate combination with oil at 0.5 per cent was markedly superior to the lime-milk-lead arsenate mixture. Lamerson & Parker (1939) tested lead arsenate at 4 pounds per 100 gallons with and without petroleum oil for the control of codling moth. When 1 quart of oil was added, the percentage of clean apples increased from 53 to 67 per cent, an increase of 24 per cent, as a result of adding oil.

Driggers & O'Neill (1939) tested several combinations of lead arsenate, fixed nicotine and nicotine sulfate with oil for codling moth control. Their objective was to produce a mixture which would be effective against adult moths, eggs, and newly hatched larvae. Whereas sprays of lead arsenate and oil permitted 14 per cent wormy fruit, the addition of 1 pint of nicotine sulfate reduced the wormy fruit to 4 per cent. Nickels & Pierce (1940), in a series of tests on lead arsenate at 6 pounds per 100 gallons for the control of the pecan nut casebearer, *Acrobasis caryae* Grote, found that the addition of 1 per cent of summer oil usually increased the control by about 10 per cent.

Oil has lately been used to aid in the retention of lead arsenate on apples by the action of certain emulsifying agents which produce the so-called "inverted" spray mixtures. Marshall (1937) stated that the ovicidal action of the oil was slightly less in an inverted mixture. Lead arsenate at 3 pounds per 100 gallons killed 9 per cent of codling moth eggs whereas 2 quarts of summer oil added to this mixture prevented about 90 per cent of the eggs from hatching. At the same time, 2 quarts of oil per 100 gallons was the optimum amount for building a maximum deposit of lead arsenate. Worthley & Steiner (1941) tested lead arsenate and oil for codling moth control in Pennsylvania. They concluded that one inverted lead arsenate spray, timed as a second cover spray, carrying double the usual concentration of lead arsenate and applied at double the usual quantity per tree, gave a control of first brood larvae equal to that obtained with four or five ordinary lead arsenate sprays. Fleming & Baker (1936) tested paris green, alone and combined with oil, for the control of the Japanese beetle. The addition of oil reduced the efficiency of the paris green slightly.

Oil sprays have been used in some cases in conjunction with sulfur or lime sulfur applied in the dormant period. Newcomer & Yothers (1931) used weak lime sulfur solution in conjunction with 2 per cent oil emulsion for the control of San Jose scale on apples and secured a complete control. Hough (1937) tested oil and lime-sulfur alone and in combination at different strengths against cherry scale. He found that 3 per cent oil gave a control of 94 per cent, and the addition of 2 gallons of lime-sulfur increased the control to 99 per cent. In the case of 2 per cent oil, however, the addition of the same amount of lime-sulfur gave an 82 per cent control as compared to 83 per cent where the oil was used alone. Worthley & Steiner (1939) applied 2.5 gallons of lime-sulfur solution with 3 per cent oil for the control of apple aphid in the green tip stage. This mixture gave an unsatisfactory control. Farrar & Smith (1931) determined that 1.5 gallons oil and 5 pounds of flotation sulfur in 50 gallons of water was effective in controlling the San Jose scale and peach leaf curl.

Selenium has been used in conjunction with oil for the control of red spider. It has been used as a proprietary mixture of potassium hydroxide, ammonium hydroxide, sulfur, and selenium. Hoskins *et al.* (1938) recommends that certain adjuvants such as light-medium mineral oil at 1:300 be used with the selenium mixture. Moore *et al.* (1941) recommended a mixture of 1 pint of the selenium concentrate and 0.33 gallons of summer oil per hundred gallons with potassium caseinate spreader for the control of mites on apples.

From this brief review of some of the recent publications on the efficiency of combinations of toxicants and oil it is apparent that data are not at hand, in most cases, whereby the combination can be identified as inhibitory, additive, or multifold. Bliss (1939) has studied the mathematical relations between the toxicities of single poisons and pairs of poisons used together. He has developed a method of computing the toxicity of a pair of

poisons from the experimentally determined toxicities of the individual components in certain types of toxic action. His method, however, is not applicable to the majority of cases of oil emulsion combined with toxicants since more than two toxic materials are involved in most cases. Thus, in oil and pyrethrum, the oil, the emulsifying agent, pyrethrin I and pyrethrin II act as independent poisons. Kagy & Richardson (1936) computed the per cent "net mortality" of a toxicant by the formula $(x-y/x)(100)$ where x equals percentage living in the oil-treated group and y the percentage living in the group treated with oil plus toxicant. However, if this formula is used to compute the "net mortality" of the oil, an entirely different view of the action of the mixture is obtained. It may be possible to classify the action of an oil-toxicant combination as inhibitory, additive, or multifold, if the concentration of the oil and of the toxicant is selected from the lower portion of the linear part of the sigmoid dosage-toxicity curve, so that the toxicity of the mixture will still fall within the linear portion of the dosage-toxicity curve of the mixture. 9-2-41.

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A Method of Simulating Airplane Application of Insecticides to Tall Plants in Experimental Plots

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Sugar beets grown for seed in the Salt River Valley of Arizona attain a height of 5 to 6 feet, and as the seed develops the tops become so matted together that it is almost impossible to apply insecticides from the ground without damaging the crop. A number of insects have been found to attack the developing seed, but no effective control measures against these insects have been developed. For this reason practically no commercial applications of insecticides to this crop in the fruiting stage have been made, and any insecticide developed for use against these insects will probably be applied by airplane. Obviously an airplane can not be used on small experimental plots, but it was considered desirable to, in some way, apply insecticides to the plants from above to simulate airplane application. For this purpose a movable scaffold was devised and successfully used on small experimental plots of sugar beets during the 1940 season. There is every reason to believe that this equipment and technique can be satisfactorily used on any tall, densely growing crop on which it is desired to make small-scale dustings of insecticides in such a way as to simulate treatment by airplane.

CONSTRUCTION OF THE SCAFFOLD.—The scaffold consisted essentially of the following three features: Two towers, a footbridge spanned between them, and a swivel bearing, which attached the bridge to the towers and gave flexibility to the structure. A good grade of pine lumber was used throughout the structure. Carriage bolts and lag screws were used in construction except in case of the braces, which were held in place with nails. A general view is given in figure 1.

The towers were built on sled runners so that they could be towed through the

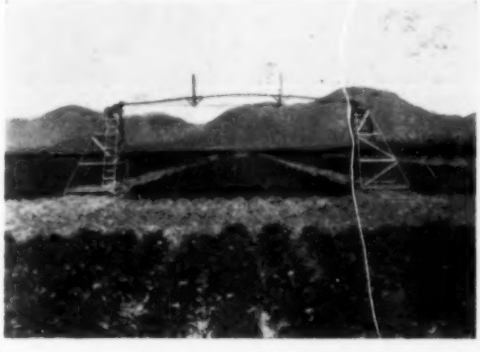

FIG. 1.—Scaffold used in applying insecticides to plants from above to simulate airplane application. Beets had not yet developed seed stalks at the time this picture was taken.

field. A close-up of one of the towers is shown in figure 2. The runners were made of 4-by-6-inch timbers and were 12 feet long. The four corner posts were constructed of 2-by-4-inch lumber and the braces of 1-by-4-inch lumber. Each tower was equipped with a built-in ladder, as shown in figure 2. One of the corner posts constituted one side of the ladder and a 2-by-2-inch tim-

ber was used for the other side; the rungs of the ladder were made of 1 by 4 inch material. A platform constructed of 1-×-4-inch flooring was built into the base of each tower and was used in carrying equipment in the field. Figure 2 shows five rotary dusters being carried on this platform. The bases of the towers were 6 by 10 feet and the tops 2 by 3 feet.

FIG. 2.—Close-up of one of the towers.

The tops of the towers consisted of frames constructed of 2-by-4-inch timbers to which 2-inch planks were bolted. Figure 3 shows a close-up of the top of one of the towers, and from this photograph it can be seen that the 2-inch planks were bolted onto the frame the long way. A short length of 2-by-10-inch plank was bolted across these planks underneath in the center of the top, to give additional strength for the bearing. (Fig. 2).

The footbridge between the towers was of the queenpost truss type of construction, as shown in figure 4. Three 2-by-10-inch planks 12 feet long were overlapped and bolted together to form the 30-foot walk, as shown in figure 4. A piece of 4-by-6-inch timber 15 inches long was bolted near each end of the walk. These blocks were primarily for the purpose of securing the ends of the rods which supported the walk, but also served as anchors for the wires used as guard rails. The details of this construction can be seen in figures 3 and 4. The rods supporting the walk were $\frac{3}{8}$-inch soft round iron rods, threaded on each end. The ends of the rods were secured in the blocks shown in figure 3 by inserting the ends of the rods through holes in the blocks and placing a large washer and two nuts on each end of the rod. The desired tension was then placed on the rods by tightening these nuts. Uprights of 2-by-4-inch timbers, 4 feet long, were bolted and braced into place at one-third and two-thirds the length of the bridge. These uprights were so placed that 15 inches projected below the plank walk and 33 inches extended above the walk, as shown in figure 4. The iron supporting rods were placed through holes in the lower end of the uprights and the wires which served as guard rails were inserted through holes in the top of the uprights. No. 9 smooth galvanized wire was used for this purpose, and turnbuckles tied into the wires near each end made it possible to maintain the desired tension.

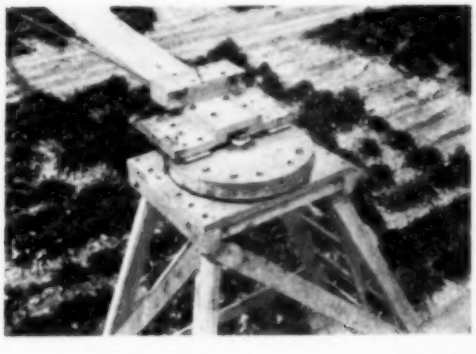

FIG. 3.—Close-up of the swivel bearing and attachment of bridge to top of tower.

Swivel Bearing.—A 2-foot piece of 2-by-12-inch plank was bolted across each end of the plank walk, as shown in figure 3. This short plank was fastened to a heavy wooden disc by means of two 12-inch strap hinges (Fig. 3). The disc was 2 feet in diameter and 4 inches thick and was constructed by bolting together two layers of 2-inch planks in such a way that the grain of the upper layer of planks was at right angles to the grain of the lower layer. A hole of the proper size to accommodate a $2\frac{1}{4}$-inch pipe was bored through the center of the disc and through the

FIG. 4.—A dust application being made to one of the experimental plots. This photograph also shows the construction of the bridge and the barriers which were used to prevent the drift of insecticides during application.

center of the top of the tower. A short length of $2\frac{1}{4}$-inch galvanized pipe was inserted through this hole and washers and nuts were placed on each end. This provided an axle on which the disc could turn. Heavy grease was placed between this disc and the top of the tower to facilitate the rotation of the disc. This disc and bearing arrangement allowed the tower to be turned beneath the bridge and yet furnished a stable attachment of the bridge to the tower. The hinges between the bridge and the disc took up the spring in the bridge and in addition prevented damage to the structure when it was being towed over uneven ground.

OPERATION IN THE FIELD.—The scaffold was moved from plot to plot by means of two automobiles, one hitched to each tower. The hitch consisted of a rope, the ends of which were attached to the ends of the sled runners. This provided a loop, which was hooked around the rear bumper of the car, thus furnishing a very simple but effective hitch (Fig. 2). In operation the scaffold was first placed in position in the beet field with the bridge spanning the plot to be treated at approximately one-fourth its length. The dust was then applied from the bridge over half the plot by means of a rotary hand dust gun equipped with an extra long delivery pipe, as shown in figure 4. The scaffold was then moved up to approximately three-fourths the length of the plot and the second half of the plot was treated from this position. One series of plots were treated with atomized pyrethrum in oil. So far as was known, no hand equipment was available with sufficient output to handle this material on experimental plots of any size. Therefore, a power sprayer of the high-pressure atomizer type was used. This equipment was mounted on a light four-wheeled rubber-tired trailer and towed behind one of the towers; the hoses were tied to the rods beneath the footbridge. Two spray rods were used and these were carried on the bridge when not in use (Figs. 4 and 5).

To prevent the drift of insecticides from one plot to another during application, barriers were placed around the plot being treated. These barriers were 9 feet

tall and consisted of light wooden frames covered with muslin. Two sets of barriers were used, and while one plot was being treated a second set of barriers was placed around the next plot to be treated. These barriers are shown in figure 4, and in the background the second set of barriers can be seen being dismantled from the plot just treated and taken ahead to the next plot. To facilitate the movement of the scaffold across from one row of plots to another, a roadway was provided at each end of the field. After the last plot in a row had been treated the scaffold was towed out into the roadway; here the towers were turned beneath the bridge until the runners were parallel with it. With the towers in this position it was possible to move the scaffold across to the next row of plots. The towers were then turned back until the runners were at right angles to the bridge or parallel to the beet rows, in which position the scaffold could then be moved along over the next row of plots in line for treatment. (Fig. 5).—7-23-41.

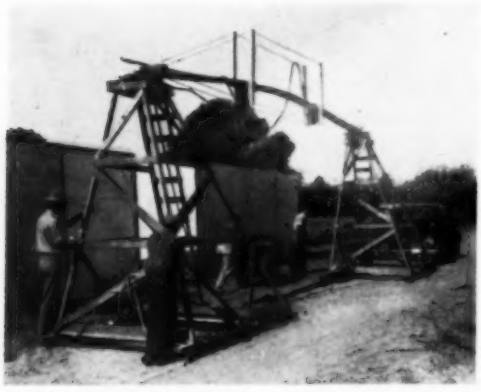

FIG. 5.—Moving the scaffold across from one row of plots to the other.

The Relation of Moisture Content of the Cotton Plant to Oviposition by *Heliothis armigera* (Hbn.) and to Survival of Young Larvae[1]

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It is well known to cotton growers and entomologists that increased rainfall the latter part of June and during July and August usually results in increased damage by the cotton bollworm, *Heliothis armigera* (Hbn.), in Texas. This has been ascribed by Quaintance & Brues (1905) to the inactivity of predators and parasites during rainy weather; to the increased production of nectar attracting ovipositing moths; and to the more rapid growth of the cotton plant producing a plentiful supply of succulent food for the larvae. Fletcher (1929) presented data indicating the attraction of bollworm moths to a 50-50 solution of molasses and water and showing the increased secretion of nectar by cotton on certain soils during rainy weather. Thomas & Dunnam (1931) showed that bollworm infestations do not always develop when there is an abundance of honey dew and nectar. They conclude that ovipositing "moths are attracted by odors emanating from rapidly growing, succulent cotton." Gaines (1932, 1933) showed that the rate of growth and fruiting are "factors that influence the moth and egg population."

In 1935 investigations were started to determine further the relationship between succulence, as measured by the moisture content of the above-ground part of the plant, and oviposition by bollworm moths.

Points were selected in representative fields of upland and bottom land cotton. Each point consisted of 100 consecutive plants in a row and was located far enough within the field to be subject only to the ecological factors peculiar to the field.

Heliothis armigera oviposition records were taken at weekly intervals from the middle of June until the experiment was closed. Both records were made on the same 100 plants at each point each week. In making the egg counts only the top, growing part of the plant was examined.

[1] Technical contribution No. 646. In cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Dept. Agr., Washington, D. C.

Table 1.—Relation between the percentage of moisture in the entire cotton plant and oviposition by *Heliothis armigera* (Hbn.).

	1935		1936		1937		1938		1939	
	Attractive Cotton	Unattractive Cotton[1]	Attractive Cotton	Unattractive Cotton[1]	Attractive Cotton	Unattractive Cotton[1]	Attractive Cotton	Unattractive Cotton[1]	Attractive Cotton	Unattractive Cotton[1]
Ave. percentage of moisture in plants	65.72	63.39	70.85	67.90	65.28	65.35	73.26	75.71	62.89	51.88
Ave. number of eggs per 100 plants	38.0	7.0	30.4	2.0	23.5	2.5	18.1	.8	45.3	2.1
Correlation between percentage of moisture in entire plant and oviposition	.267		.242		.009		−.343		.394	

[1] Cotton having fewer than 10 eggs per 100 plants classed as unattractive to ovipositing moths.

In 1935, 1936 and 1937, during the week in which the first rapid increase in oviposition occurred, 5 average normal plants were cut off at the surface of the ground at each point. Each plant was placed in a paper sack and weighed as soon as cut to 0.1 gm. They were taken then to the laboratory, where they were placed in a drying oven until no moisture could be driven off. The difference between the green weight and the dry weight gave the moisture content in grams. From this data the average percentage of water in the green plant was calculated. The correlation between moisture content and oviposition was calculated by using the average percentage of water in the plants at each point as the independent variable and the number of eggs per hundred plants at the same point as the dependent variable. Correlations were calculated according to Wallace & Snedecor (1931). The results are shown in table 1. It will be seen that during the years 1935, 1936, and 1937 the correlation between the average percentage of moisture in the entire plant and number of eggs per 100 plants was not significant.

In 1938 and 1939 a change was made in the method of obtaining data. The same procedure was followed until the plants were weighed. At this time the growing tip of the plant was cut out and weighed separately. The length of the growing tip was determined by noting the distance down the stem that the clear green of the chlorophyll was found. The weights of the growing tips were very uniform at each

Table 2.—Relation between percentage of moisture in growing tips, based on the weight of moisture in the entire plant, oviposition by *Heliothis armigera* (Hbn.) and survival of 1st and 2nd instar larvae.

	1938		1939	
	Attractive Cotton	Unattractive Cotton[1]	Attractive Cotton	Unattractive Cotton[1]
Average percentage of moisture in growing tips based on the weight of moisture in the entire plant	18.73	4.66	21.96	3.51
Average number of eggs per 100 plants	18.1	.8	45.5	2.1
Correlation between percentage of moisture in growing tips based on the weight of moisture in the entire plant and oviposition	.799[2]		.873[2]	
Average number of larvae per 100 plants 1 week after increase in oviposition			30	0
Correlation between percentage of moisture in growing tips based on the weight of moisture in the entire plant and number of larvae			.708[2]	

[1] Cotton having fewer than 10 eggs per 100 plants classed as unattractive to ovipositing moths.
[2] Significant.

point. The percentages of moisture in the growing tips based on the weight of water in the entire plant was calculated. A correlation between these figures and the number of eggs per 100 plants found at the points when the plants were cut was highly significant (Table 2).

It was again found that for 1938 and 1939, the correlation between the percentage of moisture in the entire plant and oviposition was not significant, which is in accordance with the results of 1935, 1936, and 1937 (Table 1).

The correlation between oviposition and the percentage of water occurring in the growing tips only was found to be not significant in 1938 but was significant in 1939 (Table 3). Theoretically it appears that a correlation between this factor and oviposition should be significant, but because of conflicting results this relationship is discarded until further investigation.

In 1939, records of the number of first and second instar bollworm larvae were made at each point 1 week after the plants were cut. There was found to be a highly significant correlation between the number of larvae at each point and the percentage of moisture in the growing tips based on the weight of water in the entire plant (Table 2).

This highly significant correlation occurs even though it has often been found that a high percentage of the first instar larvae is destroyed by predators.

Table 3.—Relation between the percentage of moisture in the growing tip and oviposition by *Heliothis armigera* (Hbn.).

	1938		1939	
	Attractive Cotton	[1]Unattractive Cotton	Attractive Cotton	[1]Unattractive Cotton
Average percentage of moisture in the growing tip	74.18	72.37	73.28	34.67
Average number of eggs per 100 plants	18.1	.8	45.5	2.1
Correlation between percentage of moisture in growing tip and oviposition	.0266		.726[2]	

[1] Cotton having fewer than 10 eggs per 100 plants classed as unattractive.
[2] Significant.

Attention is called to the average numbers of eggs on the attractive and unattractive cotton in 1939, showing that the more succulent cotton was far more attractive to the moths; and in this connection it should be noted that the average numbers of larvae per hundred plants may be considered as indicative of the measure of suitability of the environment for survival of the young larvae. The relationship between these figures indicating the survival of larvae and the numbers of eggs laid is especially interesting and further emphasizes the importance of succulence of cotton, in the environment of the bollworm. 3-8-41.

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SCIENTIFIC NOTES

Susceptibility of Resistant and Nonresistant Strains of the California Red Scale to Sprays of Oil and Cube Resins

A. W. CRESSMAN, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The promising results obtained with sprays of petroleum oil and cube and derris resins in the control of the California red scale, *Aonidiella aurantii* (Mask.), have led to a study of the relative susceptibility to such sprays of strains of the scale that are resistant and nonresistant to hydrocyanic acid gas. Resistant and nonresistant strains have been reared at the Whittier, Calif., laboratory since May 1935, under similar conditions but isolated from each other. The susceptibility of mature females of the two strains to sprays of oil and cube resins is discussed herein.

Lemons were selected for uniformity of size and surface texture and infested with young scales of the two strains in a laboratory warm room. When these scales were about to begin reproduction they were sprayed with emulsions of oil and of oil and cube resins.

One per cent of light medium oil plus solvent and from 0.006 to 0.013 per cent of cube resins containing 30 per cent of rotenone were used in these sprays. Two methods of combining the resins with oil were used. One method was to first dissolve the resins in a mixture of 2 volumes of dibutyl phthalate and 1 volume of trichloroethylene and add to the oil before emulsification in the proportion of 8 per cent by volume of solvent. This combination resulted in a mixed solution and suspension of resins in oil. The second method was to dissolve the resins in dibutyl phthalate and add this solution to oil at the rate of 30 per cent by volume of solvent. A clear solution of resins in oil was obtained in this way. Both types of preparation were used at each concentration of resins. Emulsions were prepared by stirring the oil-solvent-resins mixture with an equal volume of aqueous solution of ground bone glue. Two racks of eight lemons each, four infested with resistant scales and four with nonresistant scales, were treated with spray liquid from each tank. The lemons were selected so that the average of the different lots seemed uniform as to density of infestation. By removing scales that showed external signs of death before spraying, natural mortality was reduced to less than 1 per cent in those remaining. Over 2500 scales on 16 lemons were examined for each concentration.

At the two highest concentrations the solutions of the resins were more effective than the mixed solutions and suspensions, but, since the difference in the reactions of the two strains was independent of the method of incorporating the resins, the results of the two types of preparation were averaged (table 1).

The nonresistant scales sprayed with oil-solvent with no added cube resins showed a slightly higher mortality than the resistant strain, but the difference was not statistically significant. However, the difference between strains in the oil-cube resin sprays was highly significant, the resistant strain showing a greater survival in every case. Another series of laboratory tests with concentrations of cube resins ranging from 0.0067 to 0.0200 per cent gave very similar results, the resistant strain always showing a slightly greater survival. In these tests the mortalities of the two strains sprayed with oil to which no added toxicant was added were identical.

Although the difference in susceptibility of the two strains to sprays of oil and cube resins has been consistent, it has been small compared with the difference in susceptibility to hydrocyanic acid gas.

Table 1.—Relative mortality of resistant and nonresistant California red scales to oil sprays containing cube resins in various concentrations.

Concentration of Resins, Per Cent	Mortality, Per Cent	
	Resistant	Nonresistant
0	25.7	29.7
.006	77.4	81.6
.008	88.2	89.9
.013	94.1	96.8

In a typical test of the latter insecticide mortalities of 54 and 99 per cent were obtained when mature females of the two strains were simultaneously exposed to a concentration of 0.6 milligram of hydrocyanic acid per liter for 40 minutes.[1]

It should be added that the difference in effectiveness of the two methods of incorporating cube resins with oil that has been consistently obtained with laboratory-reared scales has not been found to apply to scales which matured in the field. When field-reared scales were sprayed with cube resins in oil, the dibutyl phthalate-trichloroethylene mixture has been just as effective as the increased quantity of dibutyl phthalate and has the advantage of being a better solvent for the resins than dibutyl phthalate alone.—9-2-41.

Chemical Control of *Pseudococcus comstocki* Kuw.[2]

WM. M. UPHOLT,[3] *South Carolina Experiment Station, Clemson*

Preliminary experiments in the control of Comstock's mealybug, *Pseudococcus comstocki* Kuw., on apples indicated that the usual concentrations of the ordinary spray materials would not penetrate the waxy egg masses. Since egg masses were always present in infested trees in South Carolina during 1940, it appeared that chemical control held little promise of being practical. However the present infestation in this state is restricted to one orchard and so it seemed that even expensive control, if it gave promise of possible eradication or prevention of spread, would be desirable in this case.

In these preliminary experiments it was observed that a rather high concentration of the dioctyl ester of sodium sulfosuccinate[4] did penetrate the mealy-

[1] Unpublished results by H. R. Yust and L. B. Howard.

[2] Technical Contribution No. 84 from the South Carolina Experiment Station.

[3] The writer is indebted to Mr. H. G. Barber of the U. S. National Museum for identification of the predacious mirid and to Mr. J. W. Enke, who assisted in collections and observations.

[4] Furnished by the American Cyanamid & Chemical Corporation as a 70 per cent clear solution under the trade name *Vatsol OT 70 per cent.*

bug egg masses but that it foamed too much to be used in our small experimental spray outfit which is equipped with flat, paddle-type agitators. Laboratory tests indicated that increased ease of penetration could be obtained by increasing the concentration of this material up to at least one per cent. One gallon of the 70 per cent sulfosuccinate ester was added to a five hundred gallon tank of three per cent dormant oil emulsion, and this concentration appeared to give very good penetration without foaming in the vertical tanks of this large stationary spray plant.

A rather uniform hatch of overwintering mealybug eggs in May, 1941, permitted the application of a spray at a time when both egg masses and adult mealybugs were rather scarce. Accordingly on May 24th 40 to 50 heavily infested large trees in four rows were sprayed with a mixture containing 5 quarts of the 70 per cent sulfosuccinate ester, 2.5 quarts of lauryl thiocyanate[1] and 2.5 gallons of a summer oil emulsion[2] in 500 gallons. The trees were sprayed both from the ground and from a spray tower for thorough coverage, using a total of fifteen hundred gallons on the plot. Three days later no live mealybugs were found on the sprayed trees though the unsprayed trees were heavily infested.

In the middle of June the second generation of mealybugs were hatching on the unsprayed trees and a few egg masses were found on two trees in the sprayed plot. Therefore, on June 26th when most of the eggs had hatched on the unsprayed trees, the sprayed plot was again sprayed with the same materials at the same concentrations as on May 24th. This time these materials were incorporated with a regular lead arsenate-lime cover spray.

When the apples were harvested the sprayed plot was practically free from mealybug damage. The adjacent trees were heavily infested up until August when the predacious mirid *Eurychilopterella luridula* Reut. became sufficiently plentiful to effect appreciable control. As a result of the mirid in one plot and the spray schedule in the other this entire block suffered less from mealybugs at harvest than it had at any time since it first became heavily infested. The mealybugs in another block of apples were not controlled by the mirid and they suffered heavily.

It is realized that this spray is much too expensive to be recommended as economical control. The results are not too reliable because of the lack of replications. However the indications are pretty definite that a sufficiently high concentration of the dioctyl ester of sodium sulfosuccinate will penetrate the egg masses and thus permit the use of eradicant sprays where such are deemed practical and desirable. —9-22-41.

[1] Obtained from E. I. du Pont de Nemours & Co., under the trade name *Loro*.

[2] Obtained from the California Spray-Chemical Company under the trade name *Orthol-K*.

Control of the Euonymous Scale

LOUIS PYENSON, *State Institute of Agriculture, Farmingdale, L. I., N. Y.*

It is rare to find the euonymous and bittersweet shrubs free from the presence of the euonymous scale *Chionaspis euonymi* Comst. On Long Island these scales overwinter as partly grown to fully grown females on the branches; and on the foliage, if the shrub is evergreen. Control is difficult during the growing season since all stages are present on the plant at the same time. Dormant spraying with a miscible oil helps only to reduce the scale population.

In early April, 1940, a 2 per cent solution of a water soluble dinitro compound[3] was applied to some heavily infested euonymous shrubs while spraying some trees. When an examination was made about one month later practically 100 per cent of the scales had dried up, and no injury to the plants was noticeable. A close check up made in the fall disclosed only a few new scales on the sprayed shrubs, while an unsprayed plant was covered with them.

These promising results led to a more thorough test of this insecticide on some heavily infested small euonymous shrubs in early April, 1941. The materials were applied with a small hand sprayer, and observations were made about a month later. Two to three hundred scales on various limbs were examined in obtaining the data in table 1.

Table 1.—Effect of dormant spray applications on the euonymous scale.

MATERIAL	DILUTION	MORTALITY, PER CENT
Elgetol	1.0%	98.5
Elgetol and *NNO*[1]	0.5% 1–1600	100.0
Elgetol and *NNO*	0.5% 1–200	99.5
Elgetol	0.5%	56.0
Miscible Oil (*Sunoco*)	5.0%	45.0
Check	—	20–25

[1] *NNO*—(Technical mannitan monolaurate). Trade mark of the Atlas Powder Co.

The data indicate that the dinitro spray is very toxic to the scale insects at a dilution of 1 per cent. Its equal effectiveness at 0.5 per cent dilution with the spreader was probably due to a greater wetting and penetrating effect. The spreader when used alone at 1 to 200 gave results but little different from the check. It seems likely that an application in the dormant season two years in succession should come close to completely eradicating the euonymous scale from infested plants.

Experiments with the dinitro sprays in the dormant season on lilacs to control the oyster shell scale indicated that the same effective dilutions killed a high percentage of the overwintering eggs under each scale. However, some eggs always escaped from the effects of the spray because of their position. Affected eggs turn light brown in color, while unaffected ones remain white.—10-14-41.

Action of Derris and Rotenone on the Firebrat[4]

C. H. RICHARDSON and E. J. SEIFERLE[5]
Iowa State College, Ames

The insecticidal action of derris and rotenone on the firebrat, *Thermobia domestica* (Packard), seems

[3] *Elgetol*—Mfgd. by the Standard Agricultural Chemicals, Inc., Hoboken, N. J.

[4] Journal paper *No. J-931* of the Entomology and Economic Zoology Section of the Iowa Agricultural Experiment Station, Ames; Project No. 136.

[5] Now with the General Chemical Company, New York, N. Y.

not to be reported in the literature. Since a record of the toxic effect of rotenone-bearing plants on this primitive insect is desirable both from theoretical and practical considerations, the results of a preliminary study, covering the periods from March 3 to 25, 1938, and from June 28 to August 6, 1939, are offered at this time.

Baits containing powdered derris and rotenone were presented to adult firebrats. The baits consisted of rolled oats, sucrose and sodium chloride, finely ground and thoroughly mixed, in the proportions, 200:10:5. Derris or rotenone were incorporated in amounts sufficient to give rotenone concentrations of 0.1 to 4.0 per cent. Most of the baits also contained a nontoxic dye, Scarlet R, in the proportion of 0.5 per cent, which served as an indicator of ingestion or refusal of the bait. Slight to heavy consumption of a dye-containing bait was revealed by a light to deep red color of the insect's body; and the presence of anything more than traces of the dye could be detected at the conclusion of an experiment by dropping the insect into chloroform.

The derris powder was a commercial product containing 4 per cent rotenone and 14 percent of total ether extractives; the rotenone was a chemically pure sample.

The insects were placed individually in shell vials, each vial containing approximately 0.03 gram of the bait and a support made of medium-weight typewriter bond paper which enabled the insect to rest

Table 1.—Mortality of the Firebrat on Baits containing Derris and Rotenone.

Material and Percentage Concentration[1]		Percentage of Insects Dead in 24 hrs.	48 hrs.	72 hrs.	96 hrs.
Derris[2]	0.1	14	18	22	22
Rotenone[2]	0.1	19	21	21	24
Derris	0.5	66	80	82	82
Derris	1.0	100			
Rotenone	1.0	46	58	62	65
Derris	4.0	100			
Rotenone	4.0	82	89	92	93

[1] Derris was incorporated in the derris baits in amounts to give the percentages of rotenone indicated.
[2] The results from each test with derris bait are based on 5 subsamples of 10 insects; for rotenone baits the results are based on 10 subsamples of 10 insects.

at will out of contact with the bait. The experimental vials were maintained at a temperature of 38° C. and relative humidity of about 70 per cent. Further details of experimental procedure are given by Seiferle *et al.* (1938) and Richardson & Seiferle (1940).

If the insects ate the bait readily, that fact was revealed quickly by the deep red color of their bodies; if the bodies of the insects were not colored and the insects appeared normal, the baits were considered to be repellent; and if the insects died without a trace of the dye in their bodies, then a contact action of the baits was suspected.

The results of the experiments are given in tables 1 and 2 which follow:

Baits containing derris at rotenone levels of 1 and 4 per cent killed the firebrats within 24 hours. Since there was no evidence of feeding, the action of the derris must have been by contact. At 0.5 per cent rotenone content, mortality from the derris bait was still considerable yet no feeding was indicated and even at 0.1 per cent, feeding was not observed until the 96 hour period when, in most instances, the chloroform test was required to detect the small amount of ingested bait.

In comparison with derris, rotenone was less toxic at all levels except 0.1 per cent; and at this concentration only a moderate degree of feeding was evident. The percentages of insects feeding on baits of this rotenone concentration departed rather widely

Table 2.—Feeding by the Firebrat on Baits containing Derris and Rotenone.

Material and Percentage Concentration		Percentage of Insects Colored by Scarlet R in 24 hrs.	48 hrs.	72 hrs.	96 hrs.
Derris[1]	0.1	0	0	0	20
Rotenone	0.1	28	32	40	64
Derris	0.5	0	0	0	0
Derris	1.0	0	0	0	0
Rotenone	1.0	4	6	8	8
Derris	4.0	0	0	0	0
Rotenone	4.0	4	8	8	8
Bait alone[2]		77	86	94	100

[1] Derris was incorporated in the derris baits in amounts to give the percentages of rotenone indicated.
[2] Based on 18 subsamples of 10 insects; the other tests were based upon 5 subsamples of 10 insects.

at all time levels from the percentages of mortality.

The experiments demonstrate that rotenone and derris are toxic to this lepismatid, and that under the conditions of these experiments toxicity results very largely from contact action. Perhaps a stomach poison effect could be induced by artificial feeding, since Tischler (1935) killed the caterpillars of several species of lepidopterous insects by oral administration of derris extracts. In these experiments, however, the baits containing the lowest content of rotenone were eaten much less readily than the control baits. This apparent repellent effect may have resulted from poisoning acquired by contact with the rotenone.

On the practical side, there would seem to be a place for derris dusts in the control of the firebrat. A dust prepared by incorporating derris to 1 per cent of rotenone in talc, clay, bentonite or other suitable carrier should prove useful for protecting stored books, documents, paper and fabrics from attack by this insect, especially in locations where the use of a poisoned food bait might prove dangerous.—9-19-41.

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Common Names

COMMON NAMES for nearly 1,100 insects have been approved by this Association. It is often objected that names are proposed for unimportant and little-known species; and a review of the approved list will leave no doubt that this is true. However, the correctness and suitability of common names are of still greater importance. Many of the common names that are proposed, and even many of those that have been approved, reflect hasty decision. Dissatisfaction with approved names is continually manifested. Combined, the 1940 and 1941 ballots contained proposals for changes in 27 previously adopted common names. Only 5 of these were approved, but 18 of them received a majority of the votes cast, although some were poor substitutes for the names which they were designed to replace.

Common names for insects are intended primarily to assist the layman to understand the entomologist. Necessarily their usage is limited by language differences and by local adherence to colloquial or vernacular names for some species, but within such limitations they may be relatively more stable than scientific names. The latter are international and must remain subject to internationally accepted rules under which changes are inevitable with the extension of taxonomic knowledge. The development of a list of stable common names that will be acceptable and helpful demands, however, that serious thought be given to their formation. The botanists have secured rather general adoption of scientific, especially generic, names as the common names for many ornamental and flowering plants. Some of these are in themselves meaningless to the layman, as, for example, gladiolus, rhododendron, verbena, euonymus, delphinium, chrysanthemum; but they have the advantage of brevity, and they are usually employed in the generic sense. In the case of insects, where there is often significant diversity in habits among members of the same genus, names are usually desired for individual species. Quite naturally the entomologist, when proposing common names, has been especially influenced by the intimate association of insects with particular plants, animals, or materials. Of the 85 common names on the 1941 ballot no less than 67 included reference to such relationships. In many cases that kind of indication is definitely desirable and advantageous, but the wisdom of the general practice may be questioned. The species involved may be equally, or more, important in other associations than that suggested by the common name, and a name which completely omits reference to the food of the insect may be more permanently suitable. However, certain approved common names do not go even far enough in expressing host restrictions. The name "vetch bruchid," for example, is applied to *Bruchus brachialis* Fahraeus; but a number of other species of bruchids also are important pests of vetch, and the name "hairy-vetch bruchid" would appear to be more fitting and distinctive for *B. brachialis* which is largely confined to the species that comprise the hairy-vetch group of the genus *Vicia*. In any case, thorough familiarity with the habits of the species is essential.

The requirement, approved at the Columbus meetings in 1939, that reasons accompany common names which are proposed for consideration by the Association is an important step in the right direction, but such reasons ought to consist of more than mere citation of previous use in some publication or other. They should establish the need for a common name and should explain convincingly why the name proposed is appropriate. Conscientious attention to this requirement will unquestionably result in improvement in the fitness of common names that are offered for approval if, at the same time, important characteristics of a good common

name are borne in mind. Such a name should be brief, euphonious, grammatically correct, accurately descriptive, and as restrictive as possible to the particular insect involved. Preferably it should consist of not more than three words, and each of these ought to be carefully chosen to touch upon some peculiarity of habit, structure, color, habitat, host association, or other characteristic that is distinctive. Usually it is advisable to include some hint of the order or group to which the species belongs, and in certain cases this can be done advantageously by employment of part of the scientific name. Indication of geographic restriction or source, which is sometimes desired, demands caution and thorough consideration of all the known facts pertaining to distribution of the species.

Common names are arbitrarily established and may be arbitrarily maintained, but, unless they are reasonably short and well formed and distinguish the insects to which they apply, any limited advantage they might possess over scientific names may be forfeited.—9-15-41.

C. F. W. MUESEBECK

OBITUARIES

Myron H. Swenk, 1883–1941

Myron H. Swenk, Chairman of the Department of Entomology of the University of Nebraska, died at his home in Lincoln on July 17, 1941, at the age of nearly 58 years. He was born at Polo (Ogle County), Illinois, August 8, 1883, but most of his boyhood was spent in Gage County, Nebraska. He was an alumnus of the University of Nebraska, having received his A.B. degree there in 1907, and his M.A. degree in 1908. From 1904 to the time of his death Prof. Swenk's life was identified with that of the Department of Entomology of the University. In 1919 he became Chairman of the Department and Entomologist of the Agricultural Experiment Station and served in that capacity until July, 1941, when ill health made it impossible for him to perform the duties of that office.

Prof. Swenk was married on April 24, 1918, to Miss Jane Chandler Bishop of Lincoln, Nebraska, who survives him. Other surviving relatives are his father, Howard Swenk, and a sister, Iva, both of Lincoln.

Prof. Swenk attained eminence both in research and teaching in two zoological fields, entomology and ornithology. Within these subjects his interests involved a wide range of endeavor with special emphasis on economic entomology, taxonomy of the Apoidea and Diptera, pollination of plants by insects, and the systematic distribution of North American mammals and birds, particularly those of the Missouri Valley region. He was author of approximately 154 (a complete list since 1936 not yet compiled) separate titles of which 54 were concerned with economic entomology; 23, systematic entomology; 12, mammalogy and 65 with ornithology. In 1938 he began publication of a series of papers under the title "Missouri Valley Fauna" which was supported from his own private funds. Four separate articles were published in this series and others were in the process of preparation at the time of his death.

As Chairman of the Department of Entomology in a state where agriculture is of first importance, Prof. Swenk was vitally concerned with problems in economic entomology. Since the days of the first settlers grasshoppers have been a problem of immense economic importance in Nebraska and from the early part of the present century until his death Prof. Swenk was directly concerned with the control of these pests, both from the standpoint of research and actual field operations. He was intrumental in securing Federal aid for controlling grasshoppers and chinch bugs during the early 1930's at a time when these pests, as well as the drouth, were particularly serious in Nebraska and at a time when circumstances were such that many of the farmers were financially unable to provide the materials necessary to protect their crops.

MYRON H. SWENK

In addition to work within his own profession Prof. Swenk always willingly gave of his time and efforts for the good of the university as a whole, being especially concerned with the maintenance of high scholastic standards. He was deeply interested in and continuously associated with the work of the Graduate College and was Chairman of the Com-

mittee on Graduate Work on the Agricultural College campus from 1912 to 1938. He was also an active and influential member of various committees concerned with the administration of University affairs.

Prof. Swenk's interest in ornithology was second only to his interest in entomology. For 29 years he was secretary-treasurer of the Nebraska Ornithologists' Union and also served as president of that organization for a year, and for a similar period as president of the Wilson Ornithological Club. For a number of years he served as Editor of the Proceedings of the Nebraska Ornithologists' Union, and had edited the *Nebraska Bird Review* since 1933. With L. Bruner and R. H. Wolcott he was editor of "Birds of Nebraska," and also was the author of "Mammals of Nebraska."

Prof. Swenk was a member of Sigma Xi, having been president of the Nebraska chapter in 1928–29, Gamma Sigma Delta, Alpha Zeta and Phi Sigma. He was a fellow of the American Association for the Advancement of Science, and a member of American Association of Economic Entomologists, the Entomological Society of America, American Ornithologists' Union, the Nebraska Academy of Science, the Philadelphia Academy of Natural Sciences, the Nebraska Wildlife Federation and the American Society of Mammalogists. His name was included among those in "Who's Who in America."

In his death Nebraska lost an outstanding citizen who had given the greater part of his life to the development of the University and the advancement of his profession. The high regard in which he was held by his associates is admirably portrayed in the following remark: "His accomplishment in both published research and in teaching registered in a relatively short career of fifty-eight years is a monument that he has left of the most enduring kind." As a teacher and a scientist Prof. Swenk will be remembered for his keen critical faculties, his excellent literary ability, his devotion to thoroughness and his untiring industry. In addition he will be remembered by those who knew him intimately as a gentleman and a friend who cannot be replaced.—9-22-41.

H. DOUGLAS TATE

George Augustus Ficht

George Augustus Ficht was born at Vandecar, Ontario, Canada, November 27, 1900, and spent his early years on the farm. He died at Auburn, Indiana, July 29, 1941, His wife Annie Hilda Ficht and his father survive him.

After graduating from high school he attended

GEORGE AUGUSTUS FICHT

Ontario Agricultural College where he obtained the degree of Bachelor of Scientific Agriculture in June, 1923. Three years later, June 1926, he obtained the degree of Master of Arts from the University of Western Ontario. In September 1926, Ficht registered in Iowa State College for further graduate work. Previous to this time he had had two and one-half years experience in corn borer research with the Canadian Entomological Service.

In March, 1927, Ficht accepted an appointment with the Department of Entomology of the Purdue University Agricultural Experiment Station, to take charge of European corn borer research, which position he held at the time of his death.

As a student George Ficht showed a native ability to master scientific principles and technical problems. He was selected for membership in Sigma Xi and Phi Kappa Phi. He was also a member of the American Association for the Advancement of Science, American Association of Economic Entomologists, Entomological Society of American, and Indiana Academy of Science.

It was my privilege to be closely associated with George Ficht for more than 14 years. He was likable, generous, a hard worker, thorough, and always careful in the planning and executing of his research investigations. Not only was he careful in planning and executing his research, but also capable in interpreting the results.

Ficht conducted research on a variety of crop pests, including gladiolus thrips, cutworms, and tomato nematodes, but by far his major contributions were those pertaining to the European corn borer. His detailed studies on the life history and habits of the corn borer, effect of date and rate of planting corn, relation of sanitary and cultural practices, such as plowing, ensiling and shredding to corn borer abundance, hybrid corn resistance and tolerance, and attractiveness of types of lights to the corn borer moths, are the bases of Indiana preventive and control recommendations for corn borer.

George Ficht lived a short life, but during those few years he achieved much. He was the author of many technical and popular papers which are valuable contributions to the science of Entomology and the results of his life work will have a permanent value to American Agriculture. We who knew him intimately will remember him as a true friend and an ingenious technician, as well as a benefactor of mankind.—8-14-41.

J. J. DAVIS

James Troop

James Troop, one of America's earliest teachers of Entomology, died at the home of his daughter in Urbana, Illinois, October 14, at the age of 88, just three months after the death of his wife at Lafayette, Indiana, his home for 57 years.

Professor Troop was born March 14, 1853, at Bennington, New York. He graduated from Michigan Agricultural College in 1878 where he was an associate of such notable scientists as Clarence P. Gillette, and Liberty Hyde Bailey. The next year he spent in doing post graduate work at Cornell University and the winter following in study at Harvard. In 1880 Professor Troop returned to Michigan Agricultural College to the Horticultural Staff, and received his Master of Science degree there in 1882.

Troop came to Purdue University in the fall of 1884, retaining his connection with this institution to the day of his death, more than 57 years. When he came to Purdue as Head of the Department of Horticulture and Entomology, there was only one other teacher on the Agricultural faculty. In addition to Entomology and Horticulture, he taught forestry, Botany, and Veterinary Science. After 28 years as Head of Horticulture and Entomology the combined department was divided and Troop took over the headship of the Entomology Department, which he held until 1920 when he became Professor Emeritus.

From 1899 to 1907 Troop was State Entomologist of Indiana, in which position he had charge of regulatory work, including nursery inspection. From

1896 to 1901 he was secretary of the Indiana Horticultural Society, of which he was president in 1933.

Because Professor Troop was a pioneer in the field of Horticulture and to a large degree responsible for the development of this industry in Indiana, he was affectionately known as the "Grand Old Man of Indiana Horticulture." Many of the achievements in this field in Indiana may be attributed to his farsightedness and pioneer work.

As a teacher Troop was outstanding as evidenced by the facts remembered and fond recollections expressed by his many former students.

Aside from his official duties with Purdue University, Professor Troop was active for many years in University and community affairs. He was charter member of the Purdue Chapters of Alpha Zeta and Acacia fraternity. He was past commander of the Lafayette Commandery of Knights Templars, of which he was also prelate for 33 years. He was active in church circles, being superintendent of the Baptist Church Sunday School and Deacon of the same church for many years.

Professor Troop is survived by a daughter Helen, wife of Professor O. H. Sears of the University of Illinois, and two grandchildren, Marjorie and Gordon Sears.—J. J. DAVIS.

ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS

The 17th Rocky Mountain Conference of Entomologists was held August 17–21, Cameron Pass Camp, about 75 miles West of Fort Collins, Colorado. Eighty-two people, representing 15 states and Washington, D. C. registered. The following is a list of those directly interested in Entomology.

C. R. JONES	*Colorado*
GEO. A. DEAN	*Kansas*
ROY F. FRITZ	*Kansas*
GEO. I. REEVES	*Utah*
C. L. FLUKE	*Wisconsin*
H. C. SEVERIN	*South Dakota*
L. M. GATES	*Nebraska*
H. H. WALKDEN	*Nevada*
H. M. HARRIS	*Iowa*
W. P. HAYES	*Illinois*
C. M. PACKARD	*Washington, D. C.*
CLAUDE WAKELAND	*Colorado*
R. T. COTTON	*Kansas*
JACK KELLER	*Colorado*
HARVEY MORLAN	*Colorado*
M. A. PALMER	*Colorado*
W. J. CHAMBERLIN	*Oregon*
GEO. M. LIST	*Colorado*
CARL J. WEIMAN	*Illinois*
GERALD B. SPAWN	*South Dakota*
HAROLD PRATT	*Colorado*
J. R. PARKER	*Montana*
H. B. MILLS	*Montana*
B. THOMAS SNIPES	*Wyoming*
J. R. DOUGLASS	*Idaho*
H. MESSINGER	*Colorado*
L. A. SPAIN	*Colorado*
GEORGE SCHWEIS	*Nevada*
F. B. ISELY	*Texas*
GORDON ALEXANDER	*Colorado*
M. P. JONES	*Washington, D. C.*
H. G. WALKER	*Virginia*
SAM C. MCCAMPBELL	*Colorado*
H. H. ROSS	*Illinois*
JOHN L. HOERNER	*Colorado*
WM. B. OWEN	*Wyoming*
VASCO M. TANNER	*Utah*
E. G. KELLY	*Kansas*
MAURICE T. JAMES	*Colorado*
HARRY P. CHANDLER	*Utah*

The program of the first two days was largely built around the symposium subject of "The inter-relation of entomology and the action programs." The following subjects were discussed:

Relation of land use problems to the status and population of the beet leaf hopper. . . . . J. R. DOUGLASS

Crop rotation and soil management in the control of the pale western cutworm. . . . . H. H. WALKDEN

Some insect problems in soil conservation. . . . . HAROLD B. PRATT

Tillage methods in grasshopper control. . . . . GERALD B. SPAWN

Grasshoppers in relation to the soil conservation practice of striped cropping in Western Kansas. . . . . ROY F. FRITZ

Grasshopper mites. . . . . H. C. SEVERIN

The plague situation in the Western states. . . . . HARLOW B. MILLS

Grasshopper baits. . . . . J. R. PARKER

Oil baits for the Mormon Cricket. . . . . CLAUDE WAKELAND

Coordination of grasshopper research with control.
Leaders HARLOW B. MILLS, H. C. SEVERIN, GEO. A. DEAN, ROY F. FRITZ, J. R. PARKER, C. M. PACKARD, and GEO. M. LIST.

Food specificity of grasshoppers (Acrididae and Tettigoniidae). . . . . F. B. ISELY

Say's plant bug. . . . . HARLOW B. MILLS

Insect problems of the ever normal granary. . . . . R. T. COTTON

Some effects of the national defense program on entomology. . . . . M. P. JONES

The preparation of articles for scientific journals. . . . . W. J. CHAMBERLIN

Some truck crop insects. . . HARRY G. WALKER

Notes on a cactus beetle SAM C. MCCAMPBELL

The tomato fruit worm and the squash bug. . . . . J. L. HOERNER

Some notes on the chinch bug. . . E. G. KELLY

Miris dolobratus as a possible cause of blasted heads in blue grass. . . . . C. L. FLUKE

Effects of sulfur residue upon canned tomato products. . . . . GEO. M. LIST

The European plant bug. . . . . H. M. HARRIS

On the evening of August 19 a service in memory of Dr. C. P. Gillette was held, at which Dr. Geo. H. Glover, C. L. Fluke and Geo. I. Reeves spoke.

The Conference unanimously voted to ask The American Association of Economic Entomologists to appoint an international grasshopper committee whose duty it will be to list the grasshopper studies now under way by various agencies in Canada and the U. S. and if possible to arrange for pooling each year the results of such studies and make them available to those directly interested.

The officers elected for 1942 were C. R. Jones, Chairman; W. P. Hays, Vice-chairman; Geo. M. List, Secretary, and J. L. Hoerner, Treasurer.—9–19–41.

GEO. M. LIST, *Secretary*

REVIEW

Methods of Insect Control, Part I, by Dwight Isely. ii and 121 pages. Second Edition, 1941. Burgess Publishing Co. Price. $1.50.

This book is one of two volumes on the subject of insect control which have been used for some years at the University of Arkansas as texts in a second course in applied entomology. Part I has only recently become available for general distribution; Part II is not yet available. [The author has classified insect control activities into (1) prevention of insect damage, or indirect control; (2) control by insect enemies, or biological control; (3) direct control by insecticidal or mechanical means; and (4) regulatory control. Part I deals only with the subjects of indirect control, control by insect enemies, and direct mechanical control. Part II is to treat of direct control by insecticides and control by government regulation.]

While there is a chapter devoted to each of the subject of mechanical and biological control, the emphasis is placed on indirect control methods, those practices sometimes referred to by other authors as "cultural controls." [Thus there are chapters devoted to each of the subjects of planting or harvesting with reference to seasonal history; early production; rotation; relation of crops or plants in adjacent fields; effects of mixed stands of plants; trap crops; varietal susceptibility and resistance; insect control by soil management; water management; and cultivation of crops and insect control.] In the development of these subjects, one or more examples of major insect pests are selected to illustrate each method of control under discussion. Rather full information is presented on the destructiveness, life and seasonal history, and any conditions peculiar to the pest or the crop which it attacks. With this information in hand, the suitability of the control being discussed to the conditions obtaining is pointed out. Thus the student is, in effect, set a number of problems, together with the solutions arrived at after a consideration of all essential factors bearing on the problem. It is the contention of the author that through analysis of the fundamental factors of a control problem, leading to logical solution in satisfactory control, the student will be relatively independent of the rather inflexible and frequently changed recommendations to be found in manuals of insect control.

The author has drawn extensively on his own wide experience as a successful economic entomologist. References to literature are restricted to those actually cited in the presentation of material. The book is mimeoprinted, and is not illustrated.

The result of the treatment, as outlined above, is a very happy and successful one. In the opinion of the reviewer one may get a more complete understanding of the fundamental principles on which indirect, or cultural controls are based from this, than from any other source. It is obvious that only a comparatively small number of the more important pests are included, and that the book does not attempt to take the place of more inclusive manuals of injurious insects.

P. A. Readio

Cotton States Branch 1942 Meeting

The 1942 Annual Meeting of the Cotton States Branch of the American Association of Economic Entomologists will be held in conjunction with the annual meetings of the Association of Southern Agricultural Workers in the City of Memphis, Tennessee on February 4, 5, 6, 1942.

The Cotton States Branch Headquarters will be in the De Voy Hotel which is located on Jefferson at Front Street.

Titles should be submitted to the secretary of the Cotton States Branch not later than January 13. Abstracts of papers should be presented in quadruplicate at the same time.

The local committee on arrangements is composed of Myron W. Smith, Memphis; G. M. Bentley and Simon Marcovitch, Knoxville.

John T. Creighton,
Secretary-Treasurer

National Pest Control Association Convention

The 9th Annual Convention of the National Pest Control Association was held at the Fairmont Hotel, San Francisco, California, October 27–29. The registration totaled about 250, representing every section of the United States and Canada. P. Calvert Cissell of Washington, D. C., was chosen president for the ensuing year.

Among the entomologists who attended and participated in the program were W. B. Herms, G. F. MacLeod and A. E. Michelbacher of the University of California; Arnold Mallis of the University of California at Los Angeles; J. J. Davis of Purdue University, and T. E. Snyder and Avery Hoyt of the U. S. Bureau of Entomology and Plant Quarantine. The next convention will be held in October, 1942, at Pittsburgh.

Dr. F. C. Bishopp Honored

The appointment of Dr. Fred C. Bishopp, a former president of the American Association of Economic Entomologists, to the position of Assistant Chief of the Bureau of Entomology and Plant Quarantine has recently been announced. Dr. Bishopp will have supervision of the research work of the Bureau.

Errata

Vol. 34, page 585 (August).—Footnote, column 1, should read "Contribution from the Oregon Agricultural Experiment Station.

The note reading "Contribution form the Montana Agricultural Experiment Station No. 419" in the location indicated above, should be placed at foot of column 1, page 575, in the same issue of the Journal.

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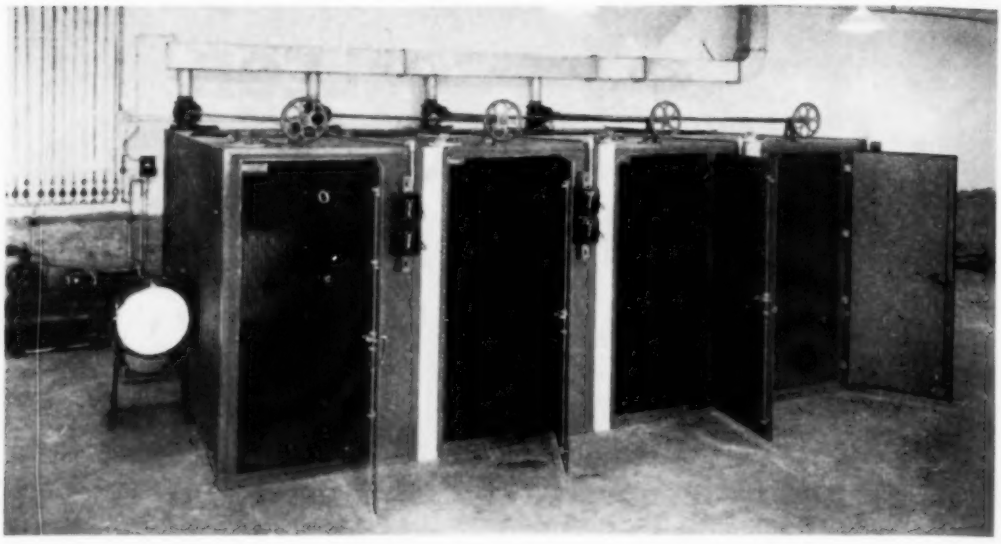

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